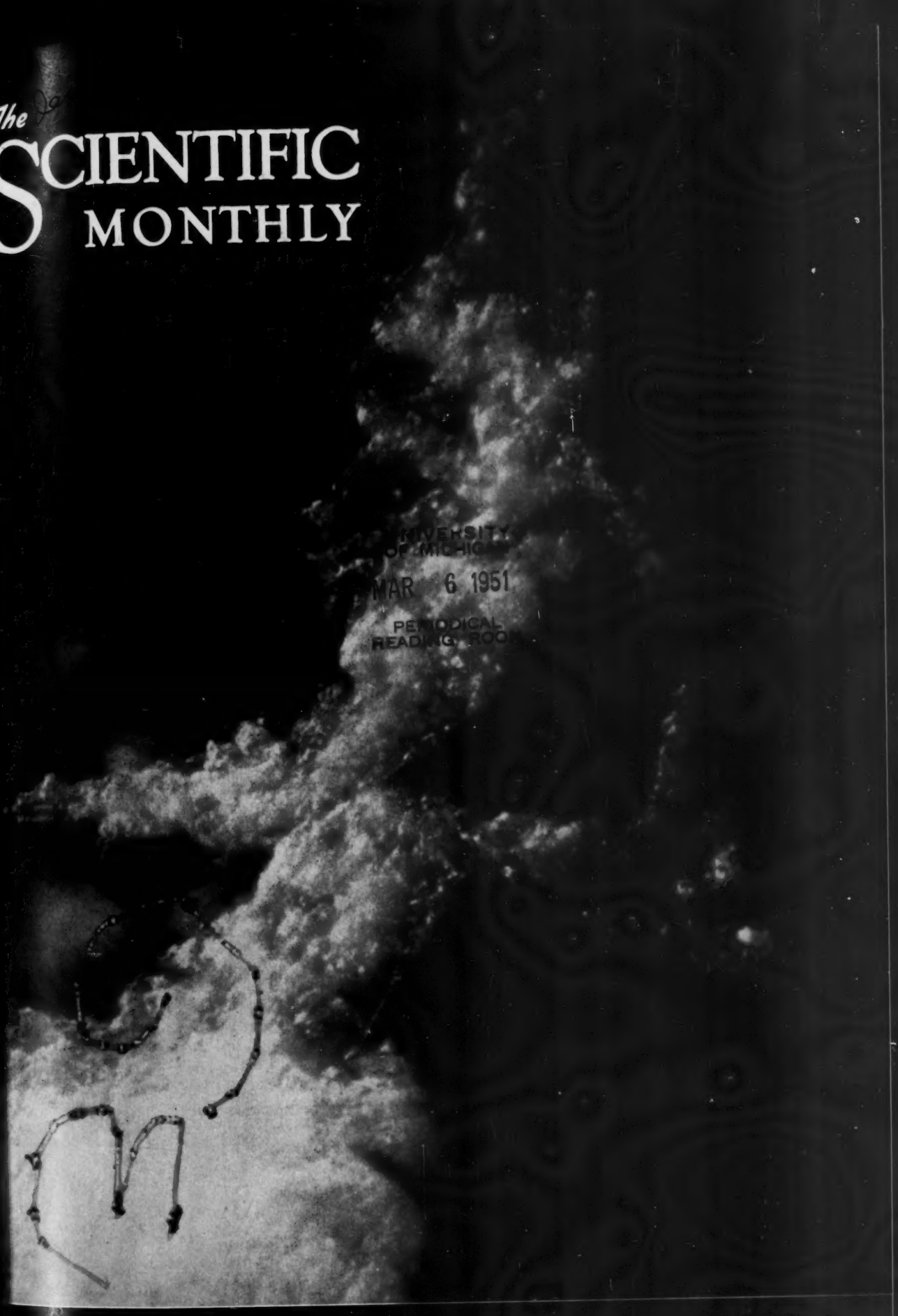
The SCIENTIFIC MONTHLY



UNIVERSITY OF MICHIGAN
MAR 6 1951
PERIODICAL READING ROOM

IT'S "LOADED" WITH BETTER TELEPHONE SERVICE

Twenty of the Bell System's newest small loading coils—like the one at the left—are housed in the long black case, mounted in a cable splice. This type of installation permits the economical extension of city cables to serve out-of-town subscribers.

MANY more wires can be crowded into a cable sheath when the wires are fine. But normally, wires don't transmit as well when they are fine and closely packed.

Bell engineers long ago learned to make wires do better work by loading them with inductance coils at regular intervals. The coils improve transmission and let messages travel farther. But originally the coils themselves were large, heavy and expensive. The cases to hold them were cumbersome and costly too.

So year after year Bell scientists squeezed the size out of coils. To make magnetic cores of high permeability they developed Permalloy. Tough but extra-thin insulation permitted more turns to a core.

New winding machines were developed by the Western Electric Company. Coil size shrunk to one-fiftieth. Some—like the one shown above—can be mounted right in cables themselves.

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THE SCIENTIFIC MONTHLY

VOL. LXXII MARCH 1951 No. 3

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Science and Technology

(From the Month's News Releases)

New Publications

The National Research Council of Canada has created six new scientific journals to take over the functions of the *Canadian Journal of Research*, which stopped publication under that name as of January 1. The new periodicals are the Canadian Journals of Physics, Chemistry, Botany, Zoology, Medical Sciences, and Technology.

The Washington Institute of Medicine has announced that its new journal, *Antibiotics and Chemotherapy*, will publish original contributions covering both research and clinical developments in both fields. Henry Welch, director, Division of Antibiotics, Food and Drug Administration, is editor-in-chief, and the advisory board is comprised of more than sixty international specialists. No. 1, Vol. 1, will bear a January 1951 date.

The A. I. B. S. Bulletin, containing "news and views in the biological sciences," will be published five times a year, in January, April, July, August, and October. $2.00 a year (50 cents a copy), or $1.00 a year to affiliate members of the American Institute of Biological Sciences. Clarence J. Hylander is editor.

The December 1950 issue of Volume 51 marked the end of the publication of the *Journal of the New York Botanical Garden*. The *Garden Journal of the New York Botanical Garden* made its bow in January 1951, combining the best features of the old *Journal*. The new publication is different in style and format and will be published bimonthly instead of monthly. The subscription price remains the same—$1.50 per year.

Industrial metallurgists and heat treaters will receive free subscriptions to the new 8-page *Heat Treat Review* by writing on their letterheads to the Editor, *Heat Treat Review*, Surface Combustion Corporation, Toledo 1, Ohio.

Stix Sticks

A new adhesive for the woodworking industry, to replace polyvinyl acetate, is said to have better waterproof qualities and to be more resistant to shock. Stix will fasten wood to rubber, plastic, metal, and other surfaces; it is also possible to eliminate the use of clamps in many woodworking operations.

Plans for Better Cars

Westinghouse is building a million miles of "electronic highway," squeezed into a single building, for the Ford Motor Company. The "highway," which is not really a roadway, is being added to the engine testing, research, and development facilities to test a car's performance under all kinds of road conditions. On the electronic "highway," a car can grind up a synthetic hill 500 or more miles long or drive thousands of miles without stopping. Electrical measuring devices will tell engineers exactly what happens inside a transmission when the gears are shifted, or how the car reacts to a heavy foot on the accelerator.

Pollen Research

An improved, portable device to collect pollen samples from the air has been developed by the Communicable Disease Center, PHS, at Savannah, Ga. Air is drawn across the adhesive side of strip of moving transparent tape by means of the suction from a fan. The tape then passes through a staining bath. Finally, the treated surface is covered with a facing piece of tape. The scientist can study under the microscope the pollen, spores, or other particles caught on the tape.

To Combat Nerve Gases

The Medical Division of the Chemical Corps disclosed recently that it has been successful in using the drug atropine in combating the effects of di-isopropyl fluorophosphate (DFP), a drug that produces symptoms similar to those caused by the so-called nerve gases. Because of its similarity to the nerve gases, DFP makes possible their laboratory observation and study. Although its potency is inferior to that of the nerve gases, DFP produces attacks that resemble the epileptic type, in which the victim's brain, muscles, and vital organs are activated for a prolonged period, finally causing exhaustion and paralysis. To be effective atropine must be administered immediately and in sufficient quantity.

Another New Paper Source?

A plant that stops erosion and improves the soil, and that can be grown from Virginia to Kansas, can be processed to make paper that can compete with that made from wood pulp both in quality and cost, Maurice E. Barker head of the University of Arkansas Department of Chemical Engineering, has reported to the American Chemical Society. Much work remains to be done, however, before practical application can be made.

Pharmaceutical Note

A simple tablet disintegration tester, based on a design originally suggested by Stoll and Gershberg (*J. Am. Pharm. Assoc.*, Sept. 1946), has been put on the market by Panray Corporation. It comes ready for operation and works from a 110-v, 60-c a.c. power supply. Besides tablet-testing the apparatus may be adapted for such purposes as determining the dissolving rate for soaps, rusting tests of metals, and many other uses.

Map Service

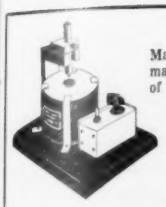
A hand-operated map reproduction device capable of making 200 copies of four-color maps in sizes up to 22″ × 29″ has been developed by the Army Engineer Research and Development Laboratories at Fort Belvoir. The duplicator uses alcohol as the dampening medium, operates under temperatures from 25° to 130° F. Typing, writing, or drawing is reproduced from a master sheet backed up by a special carbon paper. Design makes maximum use of nonstrategic materials and is transportable by air. The machine can be used commercially in preparing large charts and forms.

No Waste

Leafy plant wastes can be converted to quality feedstuffs with rotary, high-temperature alfalfa driers, already in widespread use on many farms. Leaf meals with high carotene and protein content have been produced from pea vines, Lima-bean vines, broccoli and spinach leaves, and beet tops.

[Continued on page vi]

MINERAL SEPARATOR



Makers of Meta-Magnet offer a Lab. size Electromagnetic Mineral Separator (at left) for small samples of weakly magnetic minerals such as hematite, glauconite, garnet, epidote, horneblende, etc. Has variable field strength—weighs 10 pounds. At right is demonstration model of the Meta-Magnet, a.c. electromagnet which picks up silver coins etc. Prices: Separator $59.00, Meta-Magnet $35.00, prepaid. Both operate on 110–120 Volt 60 cycle circuits.

META-MAGNET ASSOCIATES
P. O. Box 3664, Orlando, Florida

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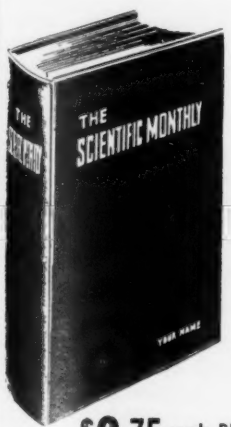

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S.M. 3-51

[*Continued from p. iv*]

Easy Answers

New circular slide rule made of plastic speeds up the answers to many nuclear research problems. Special combinations of scales used only in the field of radioactivity are arranged on the two sides of the rule. Simple settings give such values as count rate, statistical error, coincidence loss, activity of sample versus half-life, radiation flux after passage through absorbers, and other data.

Gas Detector

Explosive and flammable gases may now be accurately detected by means of an explosionproof, portable gas-analyzing instrument. Weighing only six pounds, it may easily be carried and used by watchmen, fire insurance inspectors, police officials, safety engineers, and others charged with the responsibility of protecting life and property. It is also practical for use in preventing fire or explosion on motor boats and yachts with auxiliary power.

ALA Giveaway

The American Library Association is offering $1,000 in prizes to be awarded at its meeting in Chicago in July for best statements on the power of books to influence the lives of men and women, and problems that induce the citizen to come to the library for help. The competition is sponsored by the 75th Anniversary Committee.

Double-Action Sponge

Kangaroo is a Nylonge cellulose sponge pouch that holds a long-lasting, solid cake of suds-making detergent especially condensed for such use. One side foams with suds, and the other, containing no suds, is used for wiping. The detergent works in hard or soft, hot or cold, water. Inexpensive.

Mixer

The Lanco Tumbler-Mixer can be tilted through a 90° arc for complete mixing at any angle; its drive belt is in constant tension regardless of load; and it will hold any size container—from 5-gallon cans to 1-ounce bottles, square, round, or irregular.

Science with Romance

The *Argosy*, an 85-foot sailing craft, left New York on January 30 for an around-the-world voyage that will last fourteen to eighteen months. The vessel will retrace portions of historic explorations and also examine points discovered years ago but not since revisited. Assignments include collecting of marine, botanical, and archaeological specimens; recharting for geographic groups; development of literary and photographic material; and a limited amount of trade.

Precision Device

Micro-Slide Field Finder consists of a precision rectangular-coordinate grid printed on a precisely dimensioned microscope slide 1″ × 3″. The grid covers more than half the area of the slide, so that fields of interest can be located anywhere. It is graduated into intervals of 0.1 mm, with each millimeter numbered or lettered, thus making it possible to locate a field with great accuracy. No marks of any kind are placed on the slide.

Reference Slide Collections

An International Commission for Plant Slide Exchanges has been established under the auspices of the Botanical Section of the International Union of Biological Sciences in cooperation with the California Botanical Materials Company, where the materials will be processed. All plants from the algae on are to be included, as well as all plant structures. Cooperating institutions and individuals, by payment of an annual fee of $10.00, will be able to build up reference slide collections by exchanging plant materials sent in by them for slides processed either from these materials or from those forwarded by others. Communications and shipments should be addressed to Dr. D. A. Johansen, 861 E. Columbia Ave., Pomona, Cal., USA.

Rub-R-Vive

A rubber plasticizer, when applied by cloth or brush to an old rubber surface, plasticizes the rubber and is said to impart the feel, grip, resilience, and performance of new rubber. The product is described as a noninflammable, nonvolatile liquid. Because it does not evaporate but is absorbed by the rubber, one application results in a lasting improvement. The plasticizer is already being used successfully by the printing industry. Available in pint, quart, and gallon cans, "Rub-R-Vive" is said to have excellent shelf life, and its storage does not require a fire department permit.

Drift Cards

In a project sponsored by the Fish and Wildlife Service, several thousand postcards, each sealed in a plastic container, and returnable to the Gulf States Marine Fisheries Commission, will be dropped into the Gulf of Mexico by U. S. naval aircraft during 1951. The cards are expected to drift about in the gulf currents and eventually to be cast up on beaches. Scientists will later evaluate the returns in an attempt to trace complex gulf currents, as well as the distribution and migration of commercial fishery stocks, including shrimp. By this means also the FWS is seeking ways to predict and control outbreaks of the so-called red tide.

Make Your Own Photocopies

A compact, low-priced photographic copying device, small enough to fit into a briefcase, can be carried directly to the source to quickly and easily reproduce printed, written, or sketched material. Even tightly bound book pages can be copied, because an inflatable cushion made of translucent Vinylite plastic film conforms the photographic paper to the contour of the page. Resistant to moisture, inks, and stains, the film is easily cleaned with a damp cloth to assure clear, nonfuzzy copies. The unit sells for about $43.00, with 100 sheets of photographic paper.

Aluminum Saved

Designed to conserve critical aluminum, weatherproof cluster lights for outdoor floodlighting of various kinds combine tough aluminum alloys that are precision die-cast under tremendous pressure. A removable cast aluminum cover plate sealed with a heavy cork gasket provides quick, easy access to inside wiring and speeds up installation and the addition of supplementary lampholders as well.

THE
SCIENTIFIC MONTHLY

MARCH 1951

The Quantum and Life

LORUS J. and MARGERY J. MILNE

The youthful Milnes, of the University of New Hampshire, long known for the charm and authority of their writing in the field of nature, have turned their thoughts and energies to biophysical research. Under a grant from the Cranbrook Institute of Science, they are working on a book to be called "Light Perception in Invertebrate Animals." Their investigations in this field have also been aided by the Society of the Sigma Xi, and they have just finished "Invertebrate Photoreceptors" for the National Research Council's forthcoming "Radiation Biology," which is to replace Duggar's Biological Effects of Radiation. *In 1947 they won Honorable Mention in the AAAS-George Westinghouse Science Writing competition for their story "Life of the Water Film."*

WHEN Max Planck announced his quantum theory in 1900, few biologists gave the matter a moment's consideration. After all, a quantum was purely theoretical physics. How could it have importance to an animal or plant? What difference could it make whether radiant energy such as light consisted of continuous waves (as Huygens, von Helmholtz, and Young had maintained), or of discrete units called photons (the quanta of Planck's hypothesis)? Nor were the specialists in living things at all impressed in 1911 when Albert Einstein—still almost an unknown—indicated that chemical substances affected by light must react through a precise proportionality: one molecule altered per quantum of light energy absorbed. The Einstein photochemical equivalence law, as it has come to be called, was chemistry—when the chemists got around to investigating what the mathematician meant.

All of us live and see because of photochemistry, however. For all life it is a most fundamental type of reaction. Gradually the biologists have come to appreciate the importance of the minute units of energy, the quanta we receive from the sun. It is photons trapped by the green pigment chlorophyll that can be used by a living plant for the binding together of carbon, hydrogen, and oxygen from carbon dioxide and water to form its carbohydrates and fats. This is the energy, too, that allows incorporation of nitrogen in the synthesis of proteins —those building blocks of protoplasm, that most complex, ever-changing, yet basic material of life. It is sun energy, captured a quantum at a time by a molecule at a time, that the plant must have for growth, repair, and reproduction. This same energy, released in the life processes of an animal that eats a plant, allows the herbivore corresponding possibilities. Man, as an omnivore that digests plant and animal tissues alike, obtains at second- or severalth hand the energy the green plant saved from sunlight falling on the earth. Sun energy from more remote times, stored in coal and gas and petroleum, heats our homes and powers our machinery. All this is dependent on photochemistry.

Similarly, when light affects an eye and informs an animal of what is happening around it, the proc-

ess begins as the bleaching of a pale pigment—a molecule changed per quantum of radiant energy absorbed. The bleaching initiates a nerve impulse to the control centers of the animal—and the impulses may be interpreted as vision. But the ability to see is based entirely on photochemistry—with the energy of the photons. This energy, in turn, commonly comes from the sun, or by reflection from the moon, or by scattering from the earth's atmosphere illuminated by the sun (as light from the sky, both day and night), or from stars like our sun but farther off. Man has learned to use also the energy stored by green plants in the chemical bonds of complex substances. He may release this energy in the form of heat and light where it is immediately useful—as in a hearth fire—or use the energy at remote points—as when fuel oil is burned to heat boilers to drive turbines linked to generators, to furnish energy for electric lamps and devices. Again the energy emerges as quanta, when heat or other radiant energy is evolved.

The quanta are extremely small but remarkably fast. In fact, their speed is now regarded as the ultimate possible: 3.00×10^8 meters (186,000 miles) per second. Each photon takes 8 minutes at this dizzy rate to reach the earth from the sun, and it travels in a wavelike path. There is a definite relationship between the length of each energy wave and the number of waves passing any point per

VELOCITY OF RADIANT ENERGY—A constant 3.00×10^8 meters (186,000 miles) per second

VELOCITY = FREQUENCY × WAVELENGTH
V = ν × λ
meters/sec. = cycles/sec. × meters

ENERGY OF A QUANTUM = A constant × FREQUENCY
e = h × ν
ergs = erg-secs × cycles/sec.

PLANCK'S CONSTANT, $h = 6.55 \times 10^{-27}$ erg-seconds

MECHANICAL EQUIVALENT OF HEAT
4.186×10^7 ergs = 1 Cal

NUMBER OF MOLECULES IN A GRAM-MOLECULAR QUANTITY OF MATERIAL—A constant 6.06×10^{23} molecules

One *Einstein* is a quantum per molecule in a gram-molecular quantity—expressed in Calories

Wavelength (λ) in				Type of Energy	Frequency ([ν] kc)	Quantum energy (ergs)	One Einstein (Cals)
m	mm	μ	mμ				
300,000	3×10^8	3×10^{11}	3×10^{14}	Long-wave radio	10	6.6×10^{-26}	
300	3×10^5	3×10^8	3×10^{11}		10^4	6.6×10^{-23}	
10	10^4	10^7	10^{10}	Short-wave radio	3.3×10^7	2.2×10^{-19}	
0.3	300	3×10^5	3×10^8	Microwave radar	10^9	6.6×10^{-18}	
0.003	3	3,000	3×10^6		10^{11}	6.6×10^{-16}	0.006
0.000,000,8	8×10^{-4}	0.8	800	Heat	3.8×10^{14}	2.5×10^{-12}	36.1
0.000,000,7	7×10^{-4}	0.7	700	Infrared	4.3×10^{14}	2.8×10^{-12}	40.8
0.000,000,6	6×10^{-4}	0.6	600	Red	5.0×10^{14}	3.3×10^{-12}	47.5
0.000,000,5	5×10^{-4}	0.5	500	Orange / Yellow / Green / Blue	6.0×10^{14}	4.0×10^{-12}	57.0
0.000,000,4	5×10^{-4}	0.4	400	Violet	7.5×10^{14}	4.9×10^{-12}	71.2
0.000,000,3	3×10^{-4}	0.3	300		10^{15}	6.6×10^{-12}	95.0
0.000,000,08	8×10^{-5}	0.08	80	Ultraviolet	3.8×10^{15}	2.5×10^{-11}	361
0.000,000,004	4×10^{-6}	0.004	4	Soft X-rays	7.5×10^{15}	4.9×10^{-11}	712
0.000,000,001	10^{-6}	0.001	1	Hard X-rays	3.3×10^{16}	2.2×10^{-10}	2,087
0.000,000,000,1	10^{-7}	10^{-4}	0.1	Gamma rays from radioactivity	3.3×10^{17}	2.2×10^{-9}	20,870

second (the frequency). There is likewise a close correspondence between the wavelength and the energy contained by any individual quantum. To appreciate these aspects it is important to consider briefly how quanta can be measured, and the units in which they are described.

The physicist states that the velocity of radiant energy is a constant and also represents the product of the frequency of waves and the wavelength of each. This he may represent with the Greek letters nu for frequency and lambda for wavelength, with V for velocity, and write the relationship as an equation: $V = \nu\lambda$. V is in meters per second, ν in waves per second, or "cycles" (or kilocycles, where 1,000 cycles = 1 kilocycle) per second, and λ is in meters or some more convenient decimal division of a meter. All forms of radiant energy follow this rule, whether they are radio waves, microwaves such as those used in radar, radiant heat, light, X-rays, or γ rays from radioactivity. The home radio dial is calibrated in kilocycles (frequency); short-wave operators rate their equipment by meters (wavelength); radar waves are commonly described in centimeters; light waves are measured in millimicrons (1 meter = 1 billion mμ) or in Angstrom units (1/10 as long as a mμ).

The energy of a quantum is expressed in ergs. Each erg is enough to lift a milligram (1/65 of a grain) of material a centimeter (2/5 of an inch) at sea level, against the force of gravity. Ergs are so small that they are often considered 37 trillion at a time (as a horsepower-hour), but in comparison with the energy of a quantum an erg is enormous. The relationship between energy and quanta was Planck's big contribution, and it is expressed by the brief formula: $e = h\nu$. Here again ν is the frequency of the radiant energy, e is the energy of a quantum in ergs, and h is Planck's constant, equal to 6.55×10^{-27} erg-second. Hence the energy of a quantum is $6.55 \times 10^{-27}\ \nu$ erg, or 0.000,000,000,000,000,000,000,000,006,550 ν erg. For red light with a wavelength of 600 mμ, since the frequency is 5.0×10^{14}, this energy per quantum comes to 3.3×10^{-12} erg. And although 0.000,000,000,003,300 erg seems such a trivial amount of energy, it is useful to the green plant in the synthesis of the foods we eat, or of the compounds with which we build and heat our homes. It is red light that stimulates a definite sensation in our eyes.

We normally think of foods in terms of their dietetic value—measured in Calories.* The chemist thinks of chemical bonds in the same Calorie terms, but his mind may be on the molecules involved. He knows, for example, that a gram-molecular quantity of any substance contains 6.06×10^{23} molecules. This is the number of molecules in 18 grams of water, or 180 grams of grape sugar, in 271 grams of visual pigment, or 892 grams of pure chlorophyll. Yet the light-sensitive substances require a quantum absorbed per molecule changed. Following the photochemical equivalence law, it is then possible to state that each gram-molecular quantity of photosensitive material requires 6.06×10^{23} times $6.55 \times 10^{-27}\ \nu$ erg of energy to effect the change.

One further step can be taken in the same computation. The mechanical equivalent of heat has been determined to be 4.186×10^{7} ergs per Calorie. Hence the energy per gram-molecular weight of photochemical substance can be evaluated as

$$\frac{(6.06 \times 10^{23}) \times (6.55 \times 10^{-27})}{4.186 \times 10^{7}} \nu \text{ Calories.}$$

This turns out to be $9.48 \times 10^{-11}\ \nu$ Calories, and since the value of the frequency (ν) is readily available, the quantity can be expressed in Calories for any given wavelength of radiant energy. It is a unit called an *Einstein* and is most important in considering the relationships between quanta and life. Thus the number of Calories of energy required to change completely all molecules in a gram-molecular weight of a light-sensitive substance—one Einstein—varies with the wavelength:

At 800 mμ, in the infrared, 1 Einstein = 36.1 Cal		
700	deep red	40.8
600	orange	47.5
500	yellow-green	57.0
400	violet	71.2
300	ultraviolet	95.0

These values tell the chemist why it is that light cannot cause most chemical reactions to take place. Only a very few can begin or continue on less than 100 Calories per gram-molecular weight. Light—even in the ultraviolet—does not contain enough energy per quantum to affect the molecules on the required one-to-one basis. The numbers tell the biologist, too, that the simple equation he learned in school for the process of photosynthesis does not represent the situation fairly:

$$6\ CO_2 + 6\ H_2O + 673 \text{ Calories of energy} \xrightarrow[\text{chlorophyll in a cell}]{\text{in the presence of}} C_6H_{12}O_6 + 6\ O_2.$$

The $C_6H_{12}O_6$ (grape sugar) contains bound up within itself the 673 Calories per gram-molecular weight (180 g), as any dietitian knows. This amounts to 112.2 Calories per carbon atom, and no radiant energy absorbed in photosynthesis can take the single carbon atoms in carbon dioxide to the higher energy level 112.2 Calories above by going

* Large Calories = kilocalories.

a quantum per molecule in a single step. Since the carbon gets there, more steps must be involved. In orange light at 600 mμ (47.5 Cal/Einstein), at least *three* quanta would be required per carbon atom —each carrying the process a step farther from one molecule to another with more stored energy. This might follow such a sequence as

$$6 \text{ quanta} + 6\ CO_2 \xrightarrow[\text{material in the plant}]{\text{in the presence of } X} 6 \text{ "substance } A\text{"}$$
$$(6 \times 47.5 \text{ Cals}) \qquad \text{with 47.5 Cal of chemical energy stored/carbon atom}$$

$$6 \text{ quanta} + 6 \text{ "substance } A\text{"} \xrightarrow[\text{material in the plant}]{\text{in the presence of } Y} \text{"substance } B\text{"}$$
$$(6 \times 47.5 \text{ Cals}) \qquad \text{with 95 Cal of energy stored/carbon atom}$$

$$6 \text{ quanta} + 6\ H_2O \xrightarrow[\text{material in the plant}]{\text{in the presence of } Z} 12\ H + 6\ O_2$$
$$(6 \times 47.5 \text{ Cals})$$

$$\text{"substance } B\text{"} + 12\ H \longrightarrow C_6H_{12}O_6 \text{ with 112.2 Cals/carbon atom} \qquad + 6 \times 30.3 \text{ Cal lost as heat}$$

This implies that only 30.3 Calories are lost as waste heat for each 142.5 Calories from the 3 quanta of 600 mμ orange light—which is better than 78 per cent efficiency and beyond the expectations probable in organic use of energy. Because of the discrete quality of the photons, however, greater efficiency is entirely impossible. And if the system is less efficient, at least *four* quanta must be required —wasting about 41 per cent in the process. This is more likely, and the biochemists are seeking diligently to identify the substances *A* and *B* and *C* that must be expected if the carbon is to be built up in energy-rich bonds by these four steps:

$$CO_2 + \text{a quantum} \longrightarrow \text{substance } A$$
$$\text{substance } A + \text{a quantum} \longrightarrow \text{substance } B$$
$$\text{substance } B + \text{a quantum} \longrightarrow \text{substance } C$$
$$\text{grape sugar} \longleftarrow \text{substance } C + \text{a quantum}$$

Even more steps and still less efficiency are entirely possible, but the number of intermediate chemical substances to be sought increases simultaneously.

It would be most helpful if the number of quanta could be measured directly. Then the number of steps would be clear, and the total of intermediate substances to be sought could be cited with confidence. Unfortunately it is difficult to measure energy at such low levels, and in the photosynthesis problem there are additional complications. The green plant, like any other living thing, is constantly using up energy in life processes, taking in oxygen and liberating carbon dioxide in ordinary respiration. When small amounts of light are supplied, the plant uses its stored foods less rapidly, needs less oxygen from the atmosphere, gives out smaller quantities of carbon dioxide, and makes use of the quanta furnished as illumination. Still brighter light carries this procedure to a "compensation point," where the respiratory needs are balanced completely by the photosynthetic liberation of oxygen, use of carbon dioxide, and supply of energy from light. Beyond this point the plant has oxygen to spare and waste, a greater need for carbon dioxide from its environment, and can profit still more from the light energy received. It wastes more of the light, too, so that efficiency drops and the operation is more obscure.

Max Planck was elected a Nobel Laureate in 1918. Already the quantum approach to photochemistry was being used in physiology. A fellow-German, Otto Warburg, had devised a remarkably simple and efficient technique for investigating the light and gas requirements of standardized suspensions of the single-celled alga, *Chlorella*. In 1922 and 1923, the *Zeitschrift für physikalische Chemie* carried reports by Warburg and Negelein indicating that *Chlorella* required approximately 4 quanta per carbon-dioxide molecule if photosynthesis proceeded in very low light intensities—just above the compensation point. Such efficiency was so close to the theoretical maximum that Warburg's work was checked promptly—and verified. Warburg was awarded a Nobel prize for these and other related outstanding investigations (1931). Then Farrington Daniels tried another approach to the problem, and found a minimum of 10 quanta per carbon-dioxide molecule (1938). This work, too, seemed valid, though it contradicted the high efficiency found by Warburg. Physiologists tried to find a basis for the difference. Emerson and Lewis

believed Daniels' value to be more reliable, and pounced on a few details of Warburg's technique as the explanation of his "error." They had found an initial outburst of carbon dioxide when light was turned on in the apparatus, and a corresponding uptake of the same gas when the energy source ceased operation. Warburg was sufficiently nettled by these 1940 accusations that he reworked his original experiments, modified the technique enough to eliminate any such source of difficulty, and once more arrived at a quantum requirement of 4 photons per carbon-dioxide molecule (1948).

Usually such discrepant findings indicate unrecognized complexity in the process under investigation. This generalization was applied to the Warburg-Emerson controversy by James Franck (1950), with the suggestion that the photosynthetic chemistry included at least two light-sensitive reactions—one energized by 4 quanta per carbon-dioxide molecule, the other by 8 quanta. Since Warburg's results were invariably based on photosynthesis barely above the compensation point, Franck felt it probable that part of the energy of respiration was being utilized in the light-sensitive action, that Warburg was measuring the photochemical reduction of intermediate products of respiration rather than reduction of carbon dioxide alone. Such a situation might explain the extremely high efficiency of 4 quanta per gas molecule, but restrict the application of these results to a maximum rate of 1.5 times the basic respiration proceeding because the organisms were alive. Beyond this maximum, the higher quantum requirement of photosynthesis in the stricter sense may apply, leading to the measurements of Daniels and of Emerson's group.

Both these postulated reactions must depend upon chlorophyll as the light-absorbing agent, since there is no difference recognized in the relative spectral efficiencies of the light supplied. Yet even this is subject to variation. Haxo and Blinks (1950) have reported that, in the red algae (which perform photosynthesis at greater depths in the sea, where the spectral content of light is far different from that at the surface where green algae thrive), the stimulating efficiency of light is almost minimal in the two regions where chlorophyll shows maximum absorption. Although chlorophyll is present in about the same concentrations as in green algae, it is apparent that the primary light absorber in this group of plants is not chlorophyll but the water-soluble "phycobilin" pigments known as phycoerythrin and phycocyanin. The photosynthetic activity in red algae corresponds chiefly with the light absorption of phycoerythrin. Perhaps the quantum yield will be different again; it has yet to be measured.

Study of the quantum requirements of photosynthesis is providing a new approach to the immensely important engineering puzzle the green plants afford. The modern partial understanding of what goes on is an improvement over the still less complete visualization of a few years ago. But the central problem remains the same. How can a green plant trap sun energy and build it into chemical bonds, synthesizing complex compounds at ordinary temperatures, approximate acid-base neutrality, extremely low electrical potentials, and negligible concentrations of each substrate substance? Each of these is a condition diametrically different from those man requires for chemical changes in his laboratory or industrial processes.

The measurement of Calories of light energy supplied even at maximum efficiency is complicated further in the plant because the pigments trapping the energy are neither all concerned with photosynthesis nor uniform in their absorption across the spectrum. Thus chlorophylls are not found alone. Associated with them invariably are yellow pigments that absorb light and degrade it into heat energy without doing any apparent work. Evaluating these losses is essential to a valid measure of photosynthetic energy requirements, and various devices have been used to achieve acceptable values.

In studying the quantum aspects of light perception in animals, the picture is considerably happier. There is no conflict with respiration, and an experimenter can serve as his own guinea pig—using his eyes to determine how little energy can stimulate the sensation of sight. The equipment required is complex but straightforward. A source of constant illumination can be arranged to deliver light into an optical system that isolates a single wavelength, controls its intensity within known limits, and dispenses flashes through a shutter providing a predetermined duration. With a bolometer or thermopile the energy output of the monochromatic light can be measured for each brightness setting (with the shutter open), and then the number of ergs in any single flash (say 1/1,000 second long) can be computed. If this flash is arranged to illuminate the inside of the experimenter's eye, and he responds to the energy with a sensation of sight, the conclusion is reached that this number of quanta was adequate.

The first worker to investigate the energy relations in vision was the man who first invented an instrument capable of measuring radiations quan-

titatively. S. P. Langley, who devised the bolometer, found that he could see a light when the trifling amount of 3×10^{-9} erg reached his eye. This measurement, published in 1889, was not duplicated on a valid scale for almost twenty years. Then J. von Kries and J. A. E. Eyster (1907) made a more precise determination and found that vision resulted from 507 mμ monochromatic light, if the energy was anywhere between 1.3 and 2.6×10^{-10} erg. Since a quantum at this wavelength contains about 3.9×10^{-12} erg, their result means that between 34 and 68 quanta were required to stimulate the sensation of sight. The same order of magnitude was reported in 1929 by J. Chariton and C. A. Lea (17–30 quanta at 505 mμ), and in 1932 by R. B. Barnes and M. Czerny (40–90 quanta at 530 mμ). The variability among these results suggested that much remained to be investigated.

The conditions under which the human eye responds to faint illumination became better known in the late 1930s and 1940s, and, since a measure of the absolute minimum of effective energy was wanted, best possible performance was essential. The eye is able to adapt itself to an enormous range of brightnesses—from full sunlight on a white beach to the dark of a woodland path under a moonless night sky—a range of a billion to one. But from thirty minutes to an hour is required to reach maximum sensitivity. Clearly this was one precaution to be taken. All mechanisms in the eye must reach maximum efficiency for night vision.

Night vision differs from day vision in many ways. The location of greatest sensitivity is no longer in the region of the fovea—where we find greatest acuity for day use of eyes. The rod cells alone respond to low intensities, and the maximum concentration of rods (hence the greatest sensitivity for dim illumination) lies about 20 degrees off-center, in a ring-shaped zone surrounding the fovea. Moreover, the greatest efficiency in response to a light area focused on the retina is elicited when these rods are illuminated by a circular beam 10 minutes in diameter. The sun and the moon each subtend about 30 minutes at the eye; a bright spot a third of this size as seen by the eye has the greatest stimulating value in night vision.

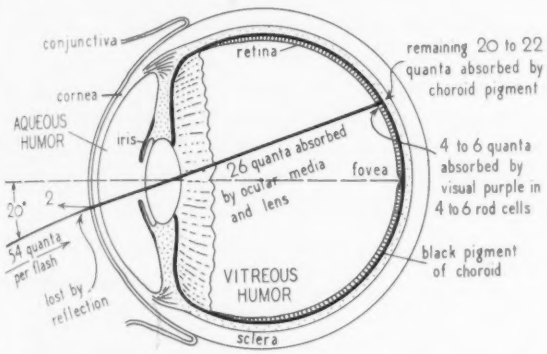
The night eye is unable to distinguish color, yet it is most sensitive to illumination having a wavelength of 510 mμ—in what becomes bluish-green when the intensity is increased. Other parts of the spectrum are less efficient, since brightness—hence energy content—must be higher if the light is to be seen. Even then, maximum effect is achieved only if the illumination is brief—less than 1/50 of a second.

The late Selig Hecht, of Columbia University, was thoroughly conversant with these aspects of night vision. He and his co-workers attacked the problem of minimum energy required for visual sensation and took every precaution to insure that the observer would be thoroughly dark-adapted, would be shown a bright area subtending 10 minutes at the eye, exactly 20 degrees away from the fovea, with light of wavelength 510 mμ, and in single flashes well below the 1/50 second limit—namely, 1/1,000 second. To be sure that the equipment brought the light into the wide-open pupil of the observer's eye, his head was firmly held in a definite location by the simple but awkward expedient of clamping his teeth over a hard impression of the upper jaw. He kept his eyes from roaming by watching a tiny red light, just bright enough to be visible and exactly 20 degrees away from the center of the diaphragm through which the test flashes of light were brought to one eye. The operator controlled light intensity (hence, energy content) coming to the shutter, and the observer chose his own time to press a button triggering the shutter—to receive a flash bright enough or not bright enough to see.

At the lower levels of sensation, the same intensity is not necessarily able to elicit the same response each time. There is an uncertainty of seeing at these threshold values, so that the tabulated results of "Yes, I saw it" (here signaled with a buzzer, since the mouth was occupied), or "No, I didn't see it," turn out to be a so-called *frequency of seeing* chart. At a higher intensity, the observer may recognize that a light was flashed 9 out of 10 presentations. Slightly dimmer, his score is 8 out of 10. Still less, 5 out of 10. Lower energy brings situations where the subject says "Yes" only once in 10 or once in 100 times. Accordingly, "threshold" has been defined as "50 per cent seeing" or "60 per cent seeing," and this factor of variability is recognized as universal.

Hecht and his co-workers, using this careful technique, obtained measurements indicating between 54 and 148 quanta needed for 60 per cent seeing, with each observer varying from day to day within a range over a factor of two. This was of course the amount of energy to reach the cornea of the eye, to produce the sensation of sight. But the cornea is smooth and wet; it reflects about 4 per cent of incident light. From the minimum value of 54 quanta, at least 2 were regularly thrown away as reflections—never entering the eye. Furthermore, the cornea, aqueous humor, lens, and vitreous humor are not completely transparent. They absorb energy, converting it into heat, and scatter

light so that it does not follow the intended path and reach the retina within the single concentrated beam. The absorption and scattering by these ocular media have been measured for the twenty-one-year-old human eye: better than 65 per cent of red light (650 mμ) passes through, but only about 10 per cent of violet light (400 mμ). The bluish-green monochromatic illumination at 510 mμ, as used by Hecht, loses about half its 52 quanta per minimal flash in reaching the retina, leaving only 26 available for absorption by the light-sensitive pigment.



Diagrammatic representation of light losses in the human eye (from data of Hecht).

The visual purple (rhodopsin) involved in night vision is found only in the terminal portions of the rod cells of the retina. To absorb all the 26 quanta, it would have to be distributed uniformly, and be a deep black. Instead, the pigment is discontinuous and a pale pink. Any quanta that are not absorbed by it pass onward through the retina and dissipate themselves as heat in the dense black pigment of the choroid coat. The best the visual purple can do is to trap 20 per cent of the incident energy—and this value agrees well with experimental data from a number of studies. This means that 4–6 quanta are absorbed by rhodopsin from the minimum requirement of 54 at the cornea—a mere 1.6×10^{-11}–2.4×10^{-11} erg/flash. Nor is this the end of the phenomenon. The area of retina on which the flash of light is focused contains about 500 rod cells. It is most unlikely that more than one of the 4–6 quanta could fall on the same rod cell; hence it is necessary to admit that if 4–6 rod cells within the 500 rod-cell population receive a quantum apiece in the same flash of light, the sensation of sight may be established. Even if the full range of 54–148 quanta found by Hecht's group be considered, this minimal requirement for 60 per cent seeing comes to just 4–14 rod cells, each receiving 3.9×10^{-12} erg of energy. And since each quantum, according to Einstein's photochemical equivalence law, causes a change in just one molecule of visual purple, a transformation of from 4 to 14 molecules within the brief flash of light is all that is required for vision.

The identification of the energy content of a flash as being 4 up to 14 quanta is based on both a measurement and a little arithmetic. The measurement of the radiant energy transmitted with the shutter open may give a value of, say, 5,000 quanta per second. Since the shutter passes light at the 5,000 quanta-per-second rate for only 1/1,000 second, the conclusion is that each flash contains 5 quanta. Actually, the 5,000 quanta per second is an average value, totaled by the thermopile, and does not represent a steady rate no matter how uniform the light source is. Since quanta are emitted and absorbed as units, the rate of emission and absorption is subject to fluctuations. As a result, some 1/1,000-second flashes contain more quanta, some less, at a given intensity. The proportions of flashes with 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, or 10 quanta in a flash whose average is 5 quanta can be computed from a probability relationship first proposed by Poisson, and known as a Poisson distribution.

This analysis brings up a fundamental problem. Does the sensitivity of the eye vary from moment to moment, resulting in the frequency of seeing characteristic of all threshold measurements? Or is the stimulus, now seen to be variable, the only source of ambiguity? Clearly, if the eye requires a certain number of quanta (and molecular transformations) to elicit the sensation of sight, then the frequency of seeing at any average quantum rate might be equal to the probability of that certain number of quanta in flashes of that brightness. Such turns out to be the case—and the uncertainty of seeing at threshold intensities is found to have a physical explanation (due to variations in the number of quanta received from a supposedly constant stimulating source), and not a biological background (the variability in sensitivity which has been attributed to living matter for many years). Five, 6 or 7 quanta do the trick—and it would be hard to imagine a mechanism using radiant energy much more efficiently.

For a while the data of Hecht and his co-workers, involving the human eye and human decisions as to whether the light flash was seen or not, were not duplicated by other techniques. Then independent corroboration was furnished by H. Keffer Hartline and his associates at the University of Pennsylvania. This time the receptor used was the large compound eye of the horseshoe crab (*Limulus*), in which single optic nerve fibers can be exposed, linked through suitable electrodes to an

electronic amplifier, and the electrical responses from single visual sense cells can be heard, seen, and recorded simultaneously—on loud-speaker, oscilloscope, and oscillograph camera. No factor for inattention, readiness, or anxiety to be "right" entered these objective measurements. Frequency-of-seeing curves were plotted, and the Poisson distribution indicated that 6–10 quanta were required for 50 per cent seeing. Careful analysis of the nerve impulses recorded from long series of identical stimulations at intensities near threshold all indicated that variability in response was purely random—due entirely to the distribution of quanta in the light flashes and not at all to variations from moment to moment in the living eye.

In terms of vision, the implications of small numbers of quanta are most interesting. Photosensitive materials, whether in leaf or eye or photographic emulsion, are relatively unstable. From 1,000 molecules in 500 adjacent rod cells it would not be surprising for 1 or 2 or even 3 to transform from the lightless to the lighted condition, spontaneously, in any hundredth of a second. Energy for these unpredictable occurrences could be taken from any number of complex systems. Photographic emulsions "fog" slowly as they age from just this sort of internal change. But the probability that 4 or 5 or 6 molecules in any given area would transform within so brief a time is far less. And it would seem that the living organism has perfected the sensitivity of the visual process to the point where events probable from chance instability are not considered, but those due to just slightly more frequent transformations of molecules—6–15 per 1/100 second—are interpreted as a definite stimulus, the sensation of sight. The development of a system to the point where one quantum on one molecule in one rod cell can cause enough change to be useful to the organism in interpreting its surroundings is in itself an enormous achievement of evolution. As Hecht pointed out, "One quantum is the smallest unit of energy, and when a retinal rod cell is capable of being brought into action by one quantum of light, the end has been reached and nothing more can be done in this direction."

A still broader view can be taken of the quantum and the photosensitive substances that absorb it. We have every reason to believe that both the photosynthetic and the visual mechanisms developed in relation to light from the sun. This light we define as "white," though it consists of a broad range of visible wavelengths from about 400 to 650 mμ. Plants make use of only a slightly broader spread of the sun's radiations—from 360 in the ultraviolet to 700 in the far deep red. But the light itself, as measured at sea level and midday, has an energy peak at about 460 mμ, falling off sharply toward the ultraviolet and much less rapidly into the infrared. The efficiency of this light in terms of photosynthesis has been measured repeatedly, and two peaks are found—one (the lesser) at 450, and hence almost in coincidence with the most energy-rich part of sunlight. The other peak is at 650, where solar energy is not quite so abundant. The trough between the two peaks in photosynthetic activity occurs at about 540 mμ and represents about 50 per cent as efficient use of quanta as is found at the 650 point. In a forest, where white sunlight filters through leaves, losing its blue and red to the foliage, the residue that reaches the ground is distinctly greenish—with a maximum brightness around 540 mμ. The maximum sensitivity of the dark-adapted eye, at 510 mμ, might be thought of as an adaptation to this dim illumination under chlorophyll-packed leaves.

The region of maximum sensitivity of the vertebrate eye corresponds to the maximum penetration of light energy into sea water—in the yellow-green around 515 mμ. The photochemistry of green plants, on the other hand, makes use of two divergent bands of the solar spectrum—one in the red (long wavelengths), the other in the blue (short wavelengths).

(*Note:* The curve showing penetration of light into sea water (——) is plotted in terms of depths, not in per cent; the top of the graph represents the water surface and depths of penetration read downward.)

But life, like the horseshoe crabs, goes back millions of years, and there were both eyes and horseshoe crabs before there were any shady forests as we know them today. In those earlier times, when the photosensitive devices in eyes were first evolving, most animals and plants were marine—many of them in coastal waters. Photosynthesis was already old. It, too, developed in shallow sea water. Yet the sea water itself, together with suspended matter in it, acts as a filter for sunlight. Average coastal sea water is more opaque to the violet end of the spectrum, somewhat less so to the red, and trans-

mits the yellow-green at 515 mμ to greater depths than any other wavelength. This is the light that was and still is available to animals, over a greater period of the day and through more range in depth, than any other part of the sun's spectrum. It would have been surprising had their eyes been developed with light-sensitive pigments that responded most efficiently in any other region of the spectrum. That the green plants with their chlorophyll must stay close to the surface where the quanta they need have not been filtered out by ocean water, whereas animals have greater freedom to operate in the seas below the plants (seeing most efficiently with the light that penetrated to those depths), can be no coincidence. When the plants, in their struggle for more light in the spectral regions their chlorophyll demanded, emerged into the atmosphere and invaded the land areas, they were already committed to using the blue and the red, to reflecting or transmitting most of the yellow-green. In their shadows many of the animals, too, climbed out of the seas and the lakes, and found again that their visual mechanisms were adequate. The peak of sensitivity that corresponded to efficient vision in light-filtering sea water was well adapted on land to dim illumination under the plants on which all animals depend ultimately for food.

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The Cleveland Meeting

REGISTRATIONS at Cleveland totaled 2,354, and every state, with the exception of Nevada, was represented (Table 1). Table 2 gives an analysis of the registrants' fields of interest, and Table 3 the fields of interest of registrants and others who saw the Annual Science Exposition.

RAYMOND L. TAYLOR
Assistant Administrative Secretary, AAAS

TABLE 1

DISTRIBUTION OF REGISTRANTS BY STATES

Ohio	787	Georgia	13
New York	232	Louisiana	12
Pennsylvania	159	Kentucky	11
Illinois	152	Rhode Island	10
Michigan	140	Oklahoma	9
Indiana	83	Delaware	8
Massachusetts	80	Florida	7
Maryland	79	South Dakota	6
Dist. of Columbia	64	Vermont	6
New Jersey	48	Mississippi	5
Wisconsin	41	South Carolina	5
Virginia	40	Washington	5
Tennessee	35	Alabama	4
Iowa	31	Montana	4
Minnesota	31	North Dakota	4
Texas	26	Oregon	4
California	24	Wyoming	4
Missouri	24	Arizona	3
Kansas	21	Arkansas	3
Connecticut	20	Colorado	3
North Carolina	19	Maine	3
Nebraska	15	New Mexico	3
New Hampshire	15	Idaho	1
West Virginia	14	Utah	1

Hawaii was represented by two registrants.

DISTRIBUTION OF FOREIGN REGISTRANTS BY COUNTRIES

Canada	32	Guatemala	1
Australia	1	Japan	1
Germany	1	Venezuela	1
Greece	1		

TABLE 2

A—*Mathematics*	48	H—*Anthropology*	20
B—*Physics*	153	I—*Psychology*	86
C—*Chemistry*	209	K—*Social and Economic Sciences*	40
D—*Astronomy*	13	L—*History and Philosophy of Science*	9
E—*Geology and Geography*		M—*Engineering*	58
Geography	24	N—*Medical Sciences*	
Geology	78	Bacteriology	17
Speleology	11	Dentistry	18
F—*Zoological Sciences*		Endocrinology	22
Embryology	25	Nutrition and Food Technology	8
Entomology	14	Pharmacy	28
Herpetology	3	Physiology	62
Histology	4	Radiobiology	26
Parasitology	127	Other Medicine	135
Protozoology	22	O—*Agricultural Sciences*	23
Zoology (all other)	295	Q—*Education*	126
FG—*Biological Sciences*		X—*Science in General*	
Biology	265	Nature study and conservation	27
Cytogenetics (including Cytology)	15	General, miscellaneous, or not stated	223
Ecology	37		
Genetics	16		
Limnology and Oceanography	6		
G—*Botanical Sciences*	61		

TABLE 3

General interest (includes wives and students)	1,304
Engineering and Technology	518
Physics (all fields)	492
Chemistry	373
Medicine	351
Science Teaching	176
Biology	156
Geology	92
Social Sciences	68
Astronomy	58
Psychology	38
Mathematics	36
History of Science	20
Anthropology	8
Total	3,690

Phenomena and Imagination*

RAYMOND J. SEEGER

Prior to World War II Raymond J. Seeger taught college physics and wrote textbooks on cultural physics. During the war he became interested in fundamental explosives research, especially shock-wave phenomena, and afterward continued research in aerophysical phenomena, particularly hyperballistics. He is now chief of the Aeroballistic Research Department, Naval Ordnance Laboratory, White Oak, Maryland, and acting director, Institute for Fluid Dynamics and Applied Mathematics, University of Maryland. He is also secretary of AAAS Section L (History and Philosophy of Science).

A GLORIOUS sunrise with sparkling dewdrops and misty veils, a rainbow arched above foaming waterfalls and gay flowers, white clouds floating above shimmering trees and blue mountains, the phantasmagoria of the sun setting on a lake, a solitary star in fading light and sombre shade, the haloed moon above ice-bearing branches and snowy fields, the scintillation of the stars overhead—these are rich treasures of man's physical heritage—these appearances, or to use the Greek word, these "phenomena." In imitation of nature's beauty, man has carved, man has painted, man has sung. He has added a human touch to his physical environment; he has added imagination to phenomena. What really matters to man is not merely what he sees with his eyes, but what he sees in things with his mind—not just eyesight, but insight. A woman once criticized the landscape painter Turner for one of his sunsets, saying, "I have never seen a sunset like that." Said he, "Don't you wish you could?"

What do we see in phenomena? What we see in anything depends essentially upon our point of view. For example, take a stick. One day I saw my child carrying a stick on her shoulder. I asked her what she had. She said, "A gun." The next day I met her galloping astride something down the path. I asked her what it was. She said, "A horse." It was the same stick. So, too, men have taken sticks and used them as rods to measure distances, as sundials to measure time, as levers to do work. In this spirit we continually inspect phenomena for their technological use. Thus atomic bombs bursting mid-air have dramatically impressed upon us the utility or the futility of science. The words uttered by the biologist Julian Huxley a decade ago have become the slogan of multitudes: "Science is not the disembodied sort of activity that some people would make out, engaged in the abstract task of pursuing universal truth, but a social function intimately linked up with human history and human destiny."

In striking contrast, however, is the testimony of the physicist Max Born. He said, "Coming straight from the Moscow Academy celebration direct to the Dublin Institute for Advanced Studies I was struck by the profound contrast between these two scientific meetings: there the materialistic idea that science has to serve social progress by producing practical results, here a spiritual attitude of pure research without regard to applications." He would have us regard phenomena from the point of view of rational inquiry. Not only the question of what use a stick, but also the question what is a stick per se! In this connection, it should be recalled that the first lovers of wisdom, the Ionians, were natural philosophers. They sought a unified materialistic explanation of nature; they tried to interpret phenomena rationally on the basis of a simple kinematic picture. Thus Thales of Miletos, the so-called father of philosophy, selected water as the primordial substance. His pupil Anaximander preferred an "ageless and deathless" substratum of matter. He called this characteristic property *physis*, and thus was born the study of physis or physics, the search for the unchanging reality behind changing phenomena. We would all agree with Aristotle's summing up of this point of view: "All men by nature desire to know."

For both these points of view, technological use and rational inquiry, imagination obviously plays an important role. What about the third point of view for phenomena, that of aesthetic enjoyment? It might seem that here the artist, painter or poet,

* Based on an address delivered to the District of Columbia Alpha Chapter of Phi Beta Kappa, The George Washington University.

has a monopoly upon imagination; that by definition the poet, the maker, has a preferential position over the scientist, the knower. I would uphold the antithesis; namely, that the poet and the scientist are on equal footing and that, in their respective spheres, they have the same power of aesthetic enjoyment. It will be recalled that one of the original nine muses who presided over song was Urania, representing astronomy, the most highly developed science of its time. I would restore modern science as a daughter of Mnemosyne and as a sister of Calliope. In this very spirit I understand the scholastic Jacques Maritain's remark in his *Education at the Crossroads* that "Physics should be taught and revered as a liberal art of the first rank, like poetry."

Phenomena, therefore, may be regarded from three different points of view: technological use, rational inquiry, aesthetic enjoyment. And to each point of view imagination is vital. Moreover, these points of view are not peculiar to any particular subject matter, but are common to all. For example, the language of men may be taught for technological use just as well as the language of Nature; physics may be taught for aesthetic enjoyment just as well as poetry. Men in different university departments, indeed, are sometimes spiritually closer than men in the same department, inasmuch as a common point of view may be more important than a common field of activity.

Now let us turn to my major thesis, that from the viewpoint of aesthetic enjoyment art and science are on the same footing relative to phenomena, or, to point my argument, that poetry and physics, in their respective spheres, utilize the same kind and the same power of imagination. To be sure, I am well aware that this thesis may not meet general acceptance. Indeed, it may suffer severe opposition, if we can judge from the common attitude of the poets. Long ago Plato noted, "There is an ancient quarrel between philosophy and poetry."

Attitude of Poets

There has always been a Greek urge to separate the universe of phenomena into a celestial realm of pure thought and into an earthly realm of factual material. Ever since the sophist Protagoras' dictum that man is the measure of all things the line of demarcation has become blurred, so that we now recognize that there is a modicum of interpretation by the observer in any so-called observed fact. Nevertheless, the poets, in the main, have carried the torch of Platonic realism in preference to the Aristotelian implication of nominalism; they have ever insisted on a sharp dividing line.

Thus Milton in his essay on "Education" says, "Poetry in comparison with science is simple, sensuous, and passionate." Shelly in his "Defence of Poetry" remarks, "Poets have been challenged to resign the civic crown to reasoners and mechanists." Wordsworth in his preface to *Lyrical Ballads* insists, "Much confusion has been introduced into criticism by this contradistinction of Poetry and Prose, instead of the more philosophical one of Poetry and Matter-of-fact, or Science." Coleridge in his *Biographia Literaria* states, "A poem is that species of composition which is opposed to science, by proposing for its immediate object, pleasure, not truth." Finally, Hunt in "What Is Poetry?" says, "Poetry begins where matter-of-fact or science ceases to be merely such." My own opinion is that the poets have not read this conception out of science, but rather that they have read it into science. It is difficult, of course, to substantiate this view with concrete evidence, inasmuch as examples are rarely given.

Hunt, however, gives the following illustration. He says, "Take a lily—that is a matter of fact; regard it as *Hexandria Monogynia*—that is science. Speak of it with Ben Jonson as the 'plant and flower of light'—that is poetry." Precision of expression, even in the Linnaean terminology, is an essential characteristic of botany, but it certainly is not all of botany, any more than precise expression is all of poetry. Perhaps I may be permitted to translate Hunt's levels of associative imagination into an example from the field of physics. Here is a stone being whirled on the end of a string—that is a matter of fact. To describe this phenomenon as a centripetal force which causes the stone to change its inertial motion along a straight line into circular motion—that is the beginning of physical understanding. To associate such circular motion, as Newton did, with the moon revolving about the earth (here no strings are attached), with the earth revolving about the sun, or, as we now do, with the solar system revolving about the constellation Sagittarius in our Milky Way galaxy; to associate, such circular motion, as Bohr did, with minute bits of electricity, electrons, revolving about an atomic nucleus—that is a higher imaginative process comparable, I believe, to Jonson's association of the lily with light. The point is that both in physics and in poetry there are different degrees of levels of imaginative creativity, and that there are comparable levels of each. In no sense can it be maintained that the levels of the one are, on the whole, higher

than those of the other. In order to substantiate this view I should like to compare further the nature of poetry with the nature of physics.

What Is Poetry?

In discussing the nature of poetry I would not seek so broad a definition that it would include all human activity to the exclusion of appropriate distinctions. Thus I would not start with Arnold's contention that "Poetry is at bottom a criticism of life—the greatness of a poet lies in his powerful and beautiful application of ideas to life—to the question: 'How to live'." This may be true of poetry; but it is hardly a distinctive characteristic. For example, it can be said equally well about history, philosophy, ethics, etc. On the other hand, I would not seek so narrow a definition that it would exclude closely related human activities, such as music, painting, sculpture. In the generic sense, then, what is the nature of poetry?

In *The Republic* Plato says that the poet "is a manufacturer of images and is very far removed from the truth." Leaving for the moment the validity of the last statement and noting merely that it is the basis of the banishing of all poets from the Platonic ideal state, we infer from it that the poet's images are not those of the photographer, but rather those of the portrait painter—they are products of the imagination. The more celebrated definition given in Aristotle's *Poetics* is that all poetry represents "modes of imitation." Although there have been reactionary trends from time to time to subjugate the imaginative process in the likenesses of phenomena made both by painter and by poet, its role has become generally accepted. Nowadays we all agree with Shelley, when he says that "Poetry, in a general sense, may be defined as the expression of the imagination. Poetry lifts the veil from the hidden beauty of the world." "Poetry is a mirror which makes beautiful that which is distorted." "A poem is the very image of life expressed in its eternal truth." We find Browning's view stated first in "Pauline": "And then thou saidst a perfect bard was one who chronicled the stages of all life." It is Wordsworth, however, who emphasizes Nature as the abode of man. He says, "Poetry is the image of man and of nature." "The poet considers the mind of man as naturally the mirror of the fairest and most interesting properties of nature." Or, to quote a modern art critic, Lionello Venturi, "Poems and paintings are works of art, and find their common grounds in the artistic attitude of imagination, expression, and experience. A poet is a painter in words and a painter is a poet in visible forms." We all agree that imagination is the distinctive quality of all art. There seems to be little room for argument here. My sole reason for recapitulating these ideas is to set before us a vivid picture of poetry for comparison with that of physics. Let us now consider the question, "What is physics?"

What Is Physics?

We have already noted the poetic Plato's antipathy to the poet as one "far removed from the truth." Elsewhere he states that "the maker of images knows nothing of true existence; he knows appearances only." As far as appearances are concerned, the physicist is in the same boat with the poet. Eddington and Milne notwithstanding, the physicist begins and ends with phenomena. He must always keep his feet on the bedrock of experience. In this respect we are reminded of the legendary story of Antaeus, the son of Terra, the earth. He was a mighty giant, an invincible wrestler, so long as he kept his feet on the ground. The hero Hercules found great difficulty in wrestling with Antaeus. Whenever Antaeus was thrown on the ground, his strength was renewed. Finally Hercules strangled him in mid-air. Similarly science becomes strangled if it is far removed from the bedrock of experience. So, too, art! In a certain sense there can be no art for art's sake. If one seeks to detach himself from life, he may become a distinguished virtuoso, a respected academician; he may play an interesting game; but he can hardly be said to be a producer of art that will move other people. Poetry and physics are both rooted in phenomena; they blossom in the free atmosphere of imagination. As far as any preconceived notion of truth is concerned, the only criterion is that the growth should be true to experience. So much for physics and phenomena. What about physics and imagination?

It must be emphasized that physics is not merely a catalogue of facts. As the mathematical physicist Henri Poincaré insists, "Science is built up with facts, as a house is with stones. But a collection of stones is no more a science than a heap of stones is a house." There is an organizing of the facts, a relating of the phenomena, an integrating of the laws. In short, we strive to get an over-all view, or, to use the Greek word for view, a "theory," which comes from the same root as theater. It is as if we were confronted with a complex jigsaw puzzle. The theorist guesses at the complete picture. Unfortunately, he does not have all the pieces, and some of those he has are mutilated. On the other hand, he is permitted to suggest new pieces to be made, i.e., to seek experimental facts. In this man-

ner some notable predictions have led to the discovery of new scientific facts. Perhaps the most celebrated instance of this heuristic technique was the finding of the planet Neptune. In 1781 the English organist-astronomer William Herschel observed the first new planet since Chaldean shepherds watched their flocks by night. Preliminary observations in the nineteenth century showed that the orbit of this new planet Uranus did not conform to calculations based on the Newtonian law of gravitation. More precise observations were made; the discrepancy was even greater. In June 1846 the French astronomer Leverrier published a quantitative explanation on the basis of the existence of some yet-to-be-found planet. On September 23 the German astronomer Galle received a letter from Leverrier in which the expected location of the new planet was given. That very evening Galle identified this new planet as Neptune. Unfortunately Uranus did not behave quite right yet. Still another planet? Its possible positions were computed in 1908 by the American astronomer Lowell. In 1930 the planet Pluto was located in one of these predicted places. Examples of such theoretical predictions and experimental verifications can be multiplied. They suggest the clarity of the view that has been imagined, they indicate the power of theory—despite its boomerang ridicule by the Nazis Lenard and Stark as a Jewish invention. Nevertheless, this type of imaginative exercise is far from being the highest level in physics. In its basic form it is illustrated as follows. Suppose a circular arc is visible, but that the rest of the curve is concealed. Immediately the complete circle is visualized.

A much higher level of imagination is involved when the whole picture is changed. For example, consider someone working on a jigsaw puzzle. He has put together some pieces, which he informs you represent the white foam on a blue sea. Upon completion, however, these same pieces are seen as white clouds in a blue sky. The over-all picture has changed; there is a different point of view, i.e., a different theory. It is important to note, however, that the observed relations of the individual parts still hold. It is merely the addition of new parts that has changed the over-all picture. Thus the discarding of one scientific theory for a new one is a sign of healthy growth; it signifies a higher point of view.

That it is possible thus to have several theories that may explain the same facts equally well is illustrated in geometry. As its name, "earth-measure," implies, geometry began as an empirical science, probably among the rope stretchers who surveyed continually the banks of the overflowing Nile. The Greek mathematician Euclid synthesized all the known facts into a logical structure. On this basis he was able to deduce that the sum of the angles in a planar triangle equals 180°. He had to undergird this structure with certain assumptions, or, to use the Greek word, *hypotheses* ("set under"). One of these demands, or postulates, was not self-evident to everyone. In the nineteenth century it was discarded independently by the Russian Lobachevsky, by the Hungarian Bolyai, and by the German Riemann. They showed that it was possible to set up equally good logical structures without this so-called parallel postulate. One of the consequences of these new geometries was that the sum of the angles of a triangle may not equal 180°. Well, why not test this relation experimentally? That is just what the German mathematician Gauss attempted with a triangle formed by three mountains, the Brocken, Inselberg, and Haberbogen. The experimental error was greater than the theoretical discrepancy. On the basis of such observations three completely different geometries are equally true to terrestrial facts. Of course, we choose the simplest (Euclid's) for everyday use.

You will have noted that I restricted my remark to terrestrial observations. For it is not true about celestial phenomena. Here empirical evidence indicates that non-Euclidean geometry must be used. For the physical laws, expressed in this geometrical language, have afforded predictions such as the deflection of light by matter, that have been verified observationally. This theory is known as general relativity. It would take us too long to trace the flashes of insight that led to this comprehensive picture, which not only incorporated geometry into physics, but changed the entire concept of gravitational force. Perhaps the power of the imagination may be suggested by the fact that initiated it.

Consider an orange. There is a certain quantity of matter, which is measured by its mass. Now, there are two ways of determining that mass: one, by the gravitational pull shown, say, on a grocery scale; the other by the change in motion produced by a force in a horizontal plane where the gravitational pull remains unchanged. Newton assumed these two masses to be equal. Precise measurements by Bessel and Eötvos later confirmed its validity. It was accepted without any question until Einstein asked, "Why?" Why should these two masses, inertial and gravitational, be the same? It must be that the phenomena themselves are physically equivalent. Imagination, limited only by the guiding beam of reason, soared to new heights; a new

picture of the universe was conceived; the theory of general relativity was developed; nor is the story finished. For our purpose, however, it is sufficient to note that many men had been aware of the basic fact; but only Einstein saw in it something significant.

Such insight—such creative imagination—has been responsible for many of the great advances in physics. I would like to cite a few more. At the close of the nineteenth century there were admitted to be two major irreconcilable physical facts, two observations that did not fit into the scheme of existing theories. One of these facts was the law of thermal radiation from a body. The German physicist Planck thought, "The fact does not agree with the theory; therefore let us build a new theory based upon the fact itself." The specific hypothesis he proposed was quite radical; it required discontinuity for classical processes that had always been regarded as continuous. This new quantum hypothesis failed to satisfy the demands of the old concepts, but it succeeded in explaining many phenomena otherwise unexplained. The same sort of question presented itself later to the Danish physicist Bohr when the nuclear model of an atom was proposed; should one start with classical theory and make a model in conformity with it or should one start with a satisfactory model despite contradictions with classical theory? He chose the latter alternative. The subsequent history of the quantum theory is a succession of such daring flights of the imagination in opposition to accepted, conventional views.

Perhaps the radical nature of such innovations may be seen more readily in another example. The second unexplained fact at the close of the nineteenth century was the constancy of the speed of light. Whether one measures it from a stationary or from a moving platform, one obtains the same answer—a paradox in view of everyday experience. For example, as one train passes another, to a passenger it will creep ahead gradually, whereas to a person standing on the ground it will fly past. Light, on the contrary, behaves differently. Whether measured from the moving train or from the earth, light travels at the same speed—regardless of how fast the train is moving. This fact does not seem to conform at all to our mechanical concepts. Said Einstein, "So much the worse for the theory; let us build a new theory based on this very fact." Thus began the so-called restricted theory of relativity. How it has completely changed our familiar concepts of space and time can be readily seen from the following discussion of simultaneity.

Is there any doubt as to whether two events occur simultaneously? Well, let us consider a passenger lighting a candle in the middle of a car on a train. Inasmuch as light travels with the same speed forward and backward, it will cover the equal distances in the same time. It is obvious to the passenger that the light will strike the two walls simultaneously. On the other hand, let us look at the lighting of the candle from the viewpoint of a person on the ground. For him, too, light travels with the same speed forward and backward. He notes, however, that the train is moving—the back of the car is moving toward the oncoming light whereas the front is moving away. It is equally obvious to him that light will not strike the two walls simultaneously. Now, which observer is correct? Does the light strike simultaneously or does it not? Evidently our ordinary concept of simultaneity has to be abandoned. Space and time have to be regarded from a more objective viewpoint.

One additional example may help us to appreciate the imaginative process at work in the conceiving of a new physical theory. Guided by certain mechanical models of the ether, which we have since discarded, the English physicist Maxwell formulated in mathematical terms the experimental discoveries of electricity and magnetism by his countryman Faraday. His sense of mathematical beauty led him to postulate the existence of a new phenomenon, electric currents in space. On the basis of this unobserved phenomenon he predicted electromagnetic waves traveling with the velocity of light; he concluded, therefore, that light itself is such an electromagnetic phenomenon. More than twenty years later all his predictions were verified, and radio was realizable. The story, however, does not end here. In 1935 the Japanese physicist Yukawa noted that a certain law of force will account for the interactions of the particles that make up an atomic nucleus—namely, neutrons and protons. The static equation satisfied by such a force is slightly different from Maxwell's equation for electric forces. Likewise, an analogous dynamic wave equation is different. Now, just as Maxwell's wave equation describes the propagation of light, so, too, Yukawa's equation suggests the existence of a new kind of wave. Moreover, just as particles of light, photons, are associated with light waves, so, too, there must be a different kind of particle associated with the new wave. Yukawa calculated the mass of such a particle to be intermediate between that of a proton and a neutron; hence, its name, "meson." A few years later mesons were actually observed in cosmic radiation; their mass agreed

with the predicted value. More recently mesons have been produced in the laboratory.

These illustrations must suffice to indicate the productive creativity of physics, the fundamental nature of phenomena, the important role of imagination. In particular, we note the free range of imagination despite the confining limits of intellectual rigor. It is this freedom combined with mathematical elegance that gives the emotional pleasure indicated by the theoretical physicist Schrödinger: "Pure knowledge contains a strong aesthetic element and is closely related to that derived from the contemplation of a work of art." Needless to say, such creative imagination is as rare among physicists as among poets. Nevertheless, whereas only a few can produce, many can learn to appreciate the product, so that the cultural significance of any liberal arts course in poetry or science must depend essentially upon its ability to evoke such appreciation, or possibly even understanding. Natural philosophy, accordingly, must be regarded as implicit in the Phi Beta Kappa humanist motto: "Philosophy, a Guide of Life."

We began with phenomena. They can be regarded from three viewpoints: that of technological use, that of rational inquiry, that of aesthetic enjoyment. In each case imagination is required for greatest realization. In the case of aesthetic enjoyment, indeed, I would uphold the thesis that science and art can be on the same level; that, within their respective spheres, they utilize the same kind of phenomena, the same power of imagination. Thus phenomena plus imagination lead to new phenomena and more imagination in a cumulative process. In the words of Shelley, who himself delighted in imaginative science,

> The everlasting universe of things
> Flows through the mind and rolls its rapid waves
> Now dark—now glittering—now reflecting gloom—
> Now lending splendour, where secret springs
> The source of human thought its tribute bring
> Of waters—with a sound but half its own.

CONSTELLATIONS

Colors and tones of earth are dimmed
Slowly—and now on the black wall,
The flaming points of stars are rimmed;
The motioned patterns forever fall.

There is Boötes with its great
Arcturus . . . Scorpio stands, the Bear
Wheels steadily; the Crown; the late
Pegasus climbs, and then the "Chair"!

Forever they make the darkness shine;
Their old light over faces runs.
Curved distance throws a slim white line—
The truth from vast and measured suns.

DANIEL SMYTHE

The Geologist's Vocabulary

KENNETH COTTINGHAM

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AS IS true of every branch of science, geology contains in its vocabulary a mixture of popular and technical terms, though it may differ in the greater proportion of words used in everyday speech—such common and well-known words as land, sea, earth, shore, coast, valley, ground, and any number of others. These, and words like them, are found as ancient cognate forms in many languages. Because of the fact that such terms never had meanings other than those we know today, and also because of the familiarity of the features they define, they may not always be recognized as having a precise geological application.

All technical speech contains words, common enough in origin, that through figurative use have come to possess sharply narrowed meanings. Some such words have become so specialized in repetitious use that, though readily understood in their narrowed application, their origins are all but forgotten. The word scale, as used in connection with the scale of a map, is a term of this kind. The expressions 'scaling a wall' and 'scaling a map' arouse such entirely different mental images that it might seem they could have nothing in common. Both, however, come from the Latin word *scala*, 'ladder.' The word in the sense of map scale is metaphorical; the two long, horizontal, parallel lines of the graphic scale are like the rails, and the short transverse divisions resemble the rungs of a ladder. The word ladder, therefore, as an expression is a common denominator to both wall-scaling and map-scaling.

Some expressions, on the other hand, might better have been borrowed from a source less familiar than English, because the use of a well-known word, with its implanted meanings and connotations, produces an entirely erroneous impression. The word pool, to most of us, arouses the image of a small body of liquid, usually water, lying quietly in a shallow surface depression. The geologist, particularly if he is a specialist in petroleum or natural gas, has his own application of the word for substances and surroundings entirely different from those referred to in the popular meaning. The geologist applies the term to an accumulation, sometimes consisting of a liquid, petroleum, and at other times consisting of natural gas. Neither is a body, or free in the sense of being held by gravity in a shallow basin, and neither is on the surface, but may be many feet or even several miles down. Both are under pressure within the voids or pore spaces between mineral grains in the entrapping rock, from which they escape with more or less energy if the rock is tapped. Either can be completely removed without affecting the reservoir's physical condition or appearance. The expression originated in the 1860s in the Appalachian region, when conditions for such accumulations were little understood, and when oil, particularly, was supposed to lie in subterranean caverns and channels. Because of association the word has led to much misinformation in the minds of those not technically familiar with the subject.

It is a fallacy, to be sure, to assume that meaning is geared directly to the nature of the thing to which the word applies, or to suppose that a primitive meaning would be passed along, without change or deviation, through long periods of time. One theory of Stoic philosophy was the belief that, if it could be discovered, the original meaning of a word would disclose the nature of the object the word designated. This search for the true meaning, or *etumon*, of a word has long since lost any significance as the Stoics conceived it, though the root is the basis for our word etymology, the study of word forms.

The geological lexicon is crowded with terms applying to paleontology, mineralogy, and proper formation names used in stratigraphy, but it is not the intention to go into such specialized forms, though the first two categories, particularly, have numerous illustrations of the kind of precise derivation that delights the lexicographer. Our review is

confined to those terms in general geology used most frequently in geological speech and writing.

Some Common Rock Names

In whatever part of the world he may have lived, and to whatever social order he belonged, man has been curious about the geology of his environment. Until comparatively recent times the interpretation of what he observed was more frequently wrong than right; nevertheless, he has always been zealous in his observations. Expressed orally at first, and later recorded in written form, many of the common terms in the geologist's lexicon reach so far back into antiquity that origins are lost.

The word clay, for instance, is said to be derived from the Latin *glus,* 'glue.' Gypsum is Greek for chalk, and from gypsum, it so happens, much of our crayon is made today. The rock known as chalk, on the other hand, is from the Latin *calx,* 'lime.' The word chalk became a part of Germanic speech, from the Latin, before the Anglo-Saxon invasion of Britain. Marl is from the old French *marle,* in turn from a Latin diminutive *marga,* which meant a particular kind of soil. Peat is Anglo-Saxon of doubtful origin, but it has been thought the word originally was in verb form and meant to mend a fire. The old English *col,* from which our word coal derives, designated a piece of glowing carbon. The word charcoal, it might be added, is from the above root and *chare,* the latter meaning to turn or change, to which the word chore is related. The word charwoman—to wander a moment from geology—has nothing to do with the fireplace, but denotes a woman who turns or changes such articles as linens, towels, or bedclothes.

Sand is an Anglo-Saxon word having the same sense today that it had originally. Grit, from Middle English *greot,* meaning a rock composed of sand and small pebbles, is an ancient word with a strange history. Grit may have lost caste because it was mistakenly supposed that the word had a slang or provincial slant, for its use in such forms as the once commonly used Berea Grit has been systematically avoided in recent years. As a matter of fact, when the words grit and sandstone are compared, the former is not only patrician, but its meaning is descriptive and exact. The case seems to be one of those instances in words where familiarity bred contempt.

Chert is supposed to have come from the Irish *ceart,* a word that signified a certain kind of nodular stone. Flint is Old English and cognate with the Greek word for tile. In Arkansas, a chertlike rock, also a fine-grained whetstone, is known as novaculite, from the Latin *novacula,* or 'razor.' It was named in Europe by the French geologist Cordier because of its abrasive qualities, adapting it to sharpening knives.

Igneous rocks, like many of the minerals composing them, were named carefully. The word igneous is from the Latin *ignis,* 'fire.' Granite is from the Latin *granum,* or 'grain,' and the Italian equivalent for granite is *granito.* The technical term for volcanic glass, obsidian, resulted from an error in spelling. A rock found in Ethiopia by a certain Obsius—whose name was incorrectly spelled Obsidius by Pliny—gave rise to the name *obsidianus lapis.* Basalt, also described by Pliny, was likewise an African rock. The dark and fine-grained igneous rock known as diabase is sometimes called trap, from the Swedish *trapp.* The Swedish word is related to *trappa,* meaning stairs, because masses of the rock so often erode in a tabular, steplike form. Those igneous rocks in which conspicuously large crystals are embedded in a finer groundmass are porphyries. The word porphyry is from the Greek for the shell known as the whelk. A crimson dye (the color was known as purple in early history) was made from the fleshy part of the whelk, so the word for the shell was transferred to the name of the color. Furthermore, a deep-red crystalline rock was used to fashion vessels and semiprecious ornaments, and because of its color, the rock was given the name porphyry for its 'purple' hue. Felsite is a dense and fine porphyry named from the German *feld* ('field') and *stein* ('stone'). Gerhard first used the word felsite in 1814, when he applied it to the groundmass of porphyries, his term being restricted to the finely crystalline mass in which the larger phenocrysts (Greek *phainein,* 'to show') were embedded. The sense and application of Gerhard's term for fieldmass has since been deflected to mean the lighter-colored but dense and earthy igneous rocks.

Trachyte, a porphyritic rock, is from the Greek *trachys,* 'rough.' A porphyritic rock showing evidences of having flowed while molten is rhyolite, from the Greek word 'to flow.' Dolerite is a fine-grained igneous rock the crystals of which are too small for the unaided eye to identify, particularly to differentiate whether hornblende or pyroxene is the principal mineral. Because these distinguishing minerals cannot be identified, the rock containing them cannot be readily classified; consequently, the name is from the Greek *dolos,* meaning 'deceit.' Diorite, on the other hand, is from the Greek root meaning 'to distinguish,' the same word from

which the now obsolete mathematical term diorism is obtained. Diorite is so named because the key mineral, usually hornblende, is easily identifiable. Norite is an igneous rock named from Norway. Phonolite is another porphyritic rock, in this case, a rock named for sound. Because of its composition and texture, it gives a ringing note when struck. Its former name was clinkstone, and by using parallel Greek roots (*phone,* 'sound'), Klaproth converted the name to phonolite.

Marble is from the Greek meaning to shine. Slate, a common metamorphic rock, is a Scotch root cognate with the Old French *esclate,* 'a splinter.' The French *eclat,* the original meaning of which was 'sharp,' is from the same root.

Kaolin, the mineralogist's general name for the aluminum silicate clays, is named from a hill in China at Kaoling (*Kao,* 'high' and *Ling,* 'hill'), where the deposit was worked for the tableware we know as china. Shales and similar rocks splitting in thin folia are termed fissile, from the Latin *fissilis,* meaning 'that which can be cleft or split.' Ledge is from the Anglo-Saxon *licgan,* 'to lie;' thus a ledge is a 'layer' of rock. The outcropping ledge was once known as a basset, a term little used today. It originated from the French root *bas,* meaning 'low.'

The term hiatus is used by the stratigraphic geologist to describe the gap in which, in proper vertical sequence, a particular stratum of rock should be found but is wanting. The word is from the Latin *hiare,* 'to yawn,' and chasm is a related word. The geologist has borrowed the word horizon and applied it to a given position or zone in the stratigraphic column. The word is Greek for 'boundary' or 'limit.' The Latin *intervallum,* meaning the distance or space between walls, gives us the word interval, used in the sense of the vertical distance separating strata. A more stilted term having the same meaning is *diastem,* Greek for 'to stand apart,' a term originally used for the tonal interval in old Greek music. Lithotope (*lithos,* 'rock,' and *topos,* 'place') is used in referring to the rock environment that characterized the original deposition of a stratigraphic unit of sedimentary rock.

The Atmosphere

Many geologic processes are related, directly or indirectly, to the atmosphere. The work of winds is eolian, from Aeolus, god of the winds, who was believed to live on one of the Aeolian (now Liparian) Islands in the Mediterranean. Pluvius was a qualifying name for Jupiter in his wetter moods, and the term pluvial is an older term for the Pleistocene or glacial period, particularly when flooded conditions prevailed as glaciers melted. Features such as the extinct glacial lakes Lahontan and Bonneville in Utah and Nevada are pluvial.

Loess is fine, siltlike, wind-blown sediment. It was first studied along the valley of the Rhine and was named by peasants in German dialect which referred to its 'loose' characteristics.

Desert is from the Latin *de,* 'away,' and *serere,* 'to join,' and a desert is therefore a disjoined part of the land. From the latter root the word series is obtained. Dune is French for sand hill, to which the English word downs is related. More strange, however, is the fact that the adverb down, meaning 'to a lower level,' is also probably derived from the word for hill—one of the few Celtic words, altogether probably not exceeding a score, that entered English before the eleventh century and were retained as part of the language.

In connection with the deserts of North Africa, several geological features have been given geographic names. Stony desert areas are *hamadas. Barchanes* are eolian deposits, smaller and more regular than dunes, usually crescent-shaped, named from Barca in Libya. *Bajir* (and *takyr*) are flat-bottomed basins separating dunes.

Exfoliation is the 'shelling off' of thin layers of boulders caused by temperature changes and atmospheric action. The word is from the Latin *exfoliare,* 'to strip off leaves.' Stones that have been worn by wind-blown sand are 'ventifacts' (made by the wind). Small stones with flattened faces worn by desert winds have been given the German name *dreikante,* for 'three' and 'edge,' and others are merely called *windkante,* 'wind' and 'edge.' A glyptolith (*glyptos,* 'carved') is a wind-etched stone. In the southwestern United States, desert boulders are frequently found with a hard-cased, highly colored exterior caused by leaching of salts or minerals from within and solidification later on the surface. These are sometimes called pocket rocks, and the hard case is called desert rind or desert varnish.

Volcanoes and Earthquakes

Eruptions of molten rock, the awesome movement of the earth's surface, and speculation about the earth's interior have fascinated people of all times, particularly those early civilizations around the Mediterranean, where volcanoes were common. The name of the Roman minor deity, Vulcan, the god of fire and patron of blacksmiths, whose forge was beneath Mount Etna, was the source of the

word volcano and also vulcanism, the general volcanic process. Crater is from the Greek word for mixing bowl. The small parasitic cone sometimes found on the side of a large volcano is known as a *bocca*, Italian for 'mouth,' which in turn comes from the Latin *bucca*, meaning 'cheek,' particularly a cheek puffed out for blowing. Plutonic, an adjective denoting deep rocks formed by crystallization from a molten state, is from Pluto, the mythical ruler of the nether regions, and the brother of Jupiter and Neptune.

The molten material from which igneous rocks solidify is a magma, from a Greek word meaning 'to knead or squeeze.' Gangue, the worthless minerals associated with ore, is from the French for matrix. Lava, from the Latin *lavere* ('to wash'), is a particularized meaning in the colloquial sense of a flood or torrent, doubtless from the torrent of molten rock pouring down the side of a volcano in eruption. Pumice is related to the Latin *spuma*, meaning 'foam,' such as the froth on boiling liquids, probably because pumice floated near volcanic islands and was skimmed from the sea. *Scoria* is Italian for 'clinker,' or 'slag,' and tufa from Latin *tophus*, a word used for soft, porous stones of various kinds.

Dermolith, from roots meaning 'skin' and 'rock,' was proposed by Jaggar for a particular kind of ropy, wrinkled lava found in Hawaii. Tholoids (*tholos*, 'dome,' and *oid*, 'like') are the rounded lava masses sometimes found within large volcanic craters. A mamelon (French for 'breast') is a similar but smoother conical lava mass. The German *kuppen* ('head') is another word for the same type of feature.

Seismism and seismic, processes or related phenomena pertaining to earthquakes, are from the Greek *seiein* meaning 'to shake.' One of the popular household cleansers is advertised as containing the mineral 'seismotite.' This invented word refers to some fine abrasive, probably pumice. The product can be shaken from the can, which may be sufficient to save the lexicology of the case! The word temblor is frequently used in newspaper reports of earthquakes, though it is not usually found in the geologist's vocabulary. The Spanish word *temblor* means an involuntary trembling, and a quaking of the earth is *temblor de tierra*, from which the term is derived. The word focus, used by all seismologists, is Latin, and originally mean 'brazier' or 'hearth.'

Terms of Diastrophism

The crust of the earth is that solid portion familiar by observation and contact. This outmoded term brings to mind a solidified shell that was once hot and plastic, and, when former theories presumed that the original earth was once a molten body, the term was well chosen. The word comes from the Latin *crusta*, related to the Greek word for 'ice,' from which the word crystal is also derived. Depending upon their densities, segments of the earth's crust are assumed to "float" on a deep interior plastic mass, and the equilibrium of these segments is known as isostasy, from the Greek words for 'equal' and 'to stand,' a term first used by Dutton in 1889. The process by which the crust is deformed—as when mountain masses are lifted or folded—is diastrophism, from Greek roots meaning 'aside' and 'to turn' or 'to twist.' The expression applied to rock forms resulting from diastrophism is tectonic, coming from the Greek word for 'carpenter,' and taking the meaning of framework or structure. Architect is a related word. Structure in geology pertains to the attitude of the rocks and the manner in which they react to stresses. The words strew and stratum are related in origin to the word structure.

A dome is a structure in stratified rocks in which the layers are elevated at a central point and slope outward from that point. The word is from the Latin *domus*, 'home,' but was altered in Italian to *Duomo*, which signified 'House of God.' Thus, because of the rounded vault that formed the roof of many churches, we have the word in its sense of a symmetrical arched structure. The geologist calls such structures quaquaversal, from Latin *quaqua* ('wheresoever') and *vertere* ('to turn'). Strata folded downward to form a trough were named by James Hall, a syncline, from 'together' and 'to lean.' A downward folding over a large area Dana named a geosyncline. The terms anticline and geanticline are respective opposites.

A great thickness of sedimentary rocks displaced as a mass and moved a considerable distance horizontally because of compressional stress is known as a nappe. The Alps provide examples. The word is French and means 'cloth,' usually in the sense of tablecloth. In Belgium, the word nappe also means an aquifer, or a water-bearing stratum or horizon. In certain parts of the world large areas of resistant granitic rocks, sloping outward like a warrior's buckler and extending downward to unknown depths, are known as shields. The Canadian shield in Ontario and Quebec, and the Scandinavian, Siberian, and Rhodesian shields are examples. Granitic and crystalline rocks forming the buried foundation for later sedimentary rocks are known

as 'basement' rocks, another imaginative term. Orogeny is the process, through diastrophism, of mountain building. It comes from the Greek *oros* ('mountain') and the root meaning 'birth.'

The inclination, or slope, of stratified beds is known as dip. Dip was first used as a noun, according to Jespersen, about the year 1600. It is Anglo-Saxon in origin, and an early meaning of the word *dyppan* was 'to baptize.' The bearing taken on a level surface at a right angle to dip in stratified rock is the strike. In the geological sense, the word may have sprung from the German *streich,* one meaning of which is 'stripe' or 'streak,' and streak, for the outcropping edge of a bed of coal, has long been used. Strike, as a level measure of grain, and strickle, a lathlike instrument for leveling such a measure, are both probably remotely related in sense to the geological term.

A rock segment, or block, raised between two faults is called a horst, from the German for 'heap,' or 'mass.' A block dropped or depressed between two parallel faults is a graben, from the German for 'trench,' or 'ditch.' A somewhat complex feature in which both structure and later erosion take parts is a klippe, German for 'cliff' or 'crag.' When older and more resistant beds are thrust over younger and less resistant beds, erosion sometimes leaves the harder overthrust rocks as "mountains without roots." Such features are also called drong mountains, a word used in the Shetland and Orkney Islands for a rocky reef rising suddenly from the sea. Occasionally older rocks are thrust horizontally over younger beds. Should subsequent erosion perforate the older rocks forming the cover, thus exposing the buried younger rocks in the lower block, the resulting feature is known as a fenster, though window, the English equivalent of the German, is used more frequently today.

A mass of igneous rock intruded into adjacent rock in such a manner that the intrusion is neither dike nor sill but irregular in form is called a chonolith, from *chono,* which means 'fused,' or 'melted,' and *lithos,* 'rock.' A mass of older rock entirely surrounded and enclosed by a later igneous magma is called a xenolith, the first part of the word from *xenos,* which means 'strange,' or 'foreign.' The terms apophysis and epiphysis are medical as well as geological. To the geologist, an apophysis is a branch or finger, still attached to the main body of igneous rock, intruded into other rock. An epiphysis is similar, except that the smaller body is not attached to its main source. The two words derive from roots meaning 'to grow from' and 'to grow upon.'

The Sea and Depositional Expressions

The word sea is itself extremely old and is supposed by some authorities to go back to the Sanskrit word for 'pour,' from which, it might be added, our word silt comes. The pronunciation of sea was *say* until about 1750. Shore is probably related to the Anglo-Saxon *sceran,* which meant 'to cut,' and the word shorn is from the same source, so that a shore is that place where the land is cut. The Latin *costa,* meaning 'rib,' and later broadened to mean 'side,' gives us the word coast, the usage originally being figurative for an animal prone on the ground. The early meaning of the word coast calls attention to the word side as used in seaside. Strand is Danish for 'margin,' or 'edge,' though the Anglo-Saxon meaning was the narrow zone between high and low tide. Ripple is probably related to Middle English, meaning 'to comb flax' or merely 'to comb,' the allusion perhaps being to the wavy appearance of anything combed. The Latin *aestuare* meant 'to surge,' particularly as the tide surges through a narrow passage, and our word estuary is a direct descendant.

Alluvium is from the Latin *alluere,* 'to wash against,' and fluvial comes from *fluvius,* 'river.' Sediment is almost directly from the Latin word *sedimentum,* which in turn is related to *sedere,* in translation, 'to sit or settle.' Gravel may be Celtic, though the old French form *gravele* was diminutive for 'sandy shore.' Deposits of sediment in gulfs and seas, rather than in the oceans proper, are known as thalassic deposits, the name coming from the mythological Thalassius, a seafaring cognomen for Hymen who, according to legend, saved a band of maidens from pirates. Neritic deposits are those along the continental shelves from low tide to a depth of 100 fathoms, and this word, too, is mythological, coming from the minor god Nereus, the father of the Nereids, who ruled over the more tranquil parts of the oceans.

The word reef, in the interpretation of a rocky shallows, is Icelandic and meant 'ribs of a skeleton.' To the geologist, a reef is usually an organic rock mass, built by corals, bryozoans, or other colonial creatures. The petrified remnants of all such plants or animals are fossils, from Latin *fossa,* or 'ditch,' which in turn came from *fodere,* 'to dig.' The organic structures known as reefs, later embedded and surrounded by sedimentary rock such as limestone or dolomite, were named bioherms by Cumings and Shrock, from the Greek roots *bios* ('life') and *herma* ('mound'). If the reef has a layered or blanket form, rather than that of a mound, it is called a biostrome, from *bios* and *stroma,* 'a bed.'

If a reef of the first type emerges to form land, and the softer rocks surrounding it have been eroded, leaving the harder reef core standing in relief, the feature is called a klint, the German for 'knob.'

The word facies is frequently found in the geology of sedimentary rocks, though the term is not defined to the full agreement of many of those who use it. In general, it is that aspect of a sedimentary unit produced or affected by similar conditions at the time of deposition. Literally, the word means 'face.' Some sedimentary deposits are marked by horizontal lines resulting from breaks in annual or seasonal deposition, much in the manner of growth lines. Such bands or lines are varves, coming from the Swedish word *varv,* meaning 'layer, tier, turn, or round,' to which the word whorl is related.

Terms Used in Glaciology

Because of their accessibility, the Alps have long been a center for the observation of geological processes. This is particularly true of the work of snow and ice in the nearly 2,000 Alpine glaciers. The word Alps is from the Latin *alpes,* meaning 'high mountains.' From the time of the early Romans, the region has been known intimately to various nationalities surrounding it, and the glacial terms in use today are variously French, Italian, German, and Austrian.

Moraine is a French word, the exact origin of which cannot be traced, though old dialectic German had a word *mur* which meant 'a rubble of broken stones,' and the Italian *mora* meant 'a pile of stones.' Avalanche is French, the verb meaning 'to descend,' coming in turn from Latin 'to the valley.' Ice-worn and basinlike rock valleys at the head of a mountain glacier are called cirques, from the Latin *circus,* a 'circle.' The roughly cylindrical and nearly vertical opening in the ice into which some glacial streams pour is known as a moulin, French for 'mill.' The sharply ridged and crested mountain peaks, owing their shape to eroding glaciers, are called aretes, which is French for 'fishbone,' and comes from the Latin *arista,* 'a beard of rye.'

Granular snow, partly consolidated into ice in the snow fields at the head of alpine glaciers is known to the Swiss as *firn,* for which the original German meaning was 'old, of last year,' or 'last year's snow.' A *riegel* is the bedrock barrier at the head of a glacier, below which the accelerated glacier movement in the narrowed valley has caused more rapid erosion and thus a steepened gradient in the valley floor. The German word means 'crossbar,' or 'bolt.' At this same point in the valley, glacial ice is often deeply crevassed at the break in the gradient of the rock floor. The crevasse is called the *bergschrund,* from the German *berg,* "mountain,' and *schrund,* 'cleft,' or 'crevice.' *Strukturboden* is a general term applied to 'stone rings' or 'stone stripes' resulting from the action of frost lifting partly loosened rock in alpine regions—the rings forming in those places where the surface is flat, and the stripes where it is steep. The German word *boden* means 'ground,' and the term therefore signifies 'ground structure.' Small basins gouged by ice in a valley floor may hold small lakes known as *colks,* after the ice has retreated or disappeared. This word is Dutch and signifies the *colk,* 'or hollow,' eroded by outrushing water at the base of a broken dike. In the United States, small lakes strung out along glaciated valleys and occupying basins formed in bedrock by ice-gouging are known as paternoster lakes, because of their general resemblance to a rosary.

Stoss, from German meaning 'thrust,' or 'push,' applies to the direction from which a glacier approached. *Roches moutonnees* are rounded rock knobs left as the result of glacial abrasion. Because such knobs slope gently on the *stoss* and more steeply on the lee sides, and because they occur in groups, they are called sheep rocks for their resemblance to a flock of sheep lying in a field.*

The troughlike hollow between the edge of retreating ice and the sand and gravel deposited by water flowing away from the ice front is a fosse, from Latin *fodere* ('to dig'), and related in derivation, but entirely unrelated in sense, to the word fossil. The word drumlin, applied to the elongated glacial hills made by ice overriding drift, is derived from the Irish *druim,* meaning 'back,' as backbone of an animal, and hence 'ridge.' The rounder hills left by streams at the edge of ice sheets and built of sand or gravel are kames, a Scotch word which is possibly a variant of 'comb.' It probably applied originally to forms more elongated and ridgelike than those in the present meaning of the word. Eskers are ridgelike hills of sand or gravel, sometimes several miles long, formed by streams flowing in ice tunnels. This word is derived from the Irish *eascra,* or 'ridge.'

The word col, in the United States, is sometimes restricted to the narrows at the former divide between two streams whose courses have been diverted or otherwise affected by glaciation. The

* When De Saussure first employed this term in 1796, he referred to hills in the Alps "having rounded summits and covered with undergrowth or grass looking like those fleecy wigs known as 'moutonnees'." In De Saussure's day the glacial origin of *roches moutonnees* was not suspected. (Chester R. Longwell. *Am. J. Sci.,* 5th Ser., 25, 503.)

word is French for 'pass,' as mountain pass, and comes from the Latin *collum,* meaning 'neck.' The word periglacial (*peri,* Greek, 'near') is used for effects in an area which, although not actually glaciated, was nevertheless so near the ice that the climate influenced the geology. Material deposited underneath glacial ice, consisting of a heterogeneous mixture of rocks, boulder clay, sand, and gravel, is known as till. There is doubt as to the origin of the word, though it was once an agricultural term in Scotland, where it meant an extremely poor soil.

Some Topographic Terms and Their Sources

The Greek *topos* ('place') and the familiar *graphia* form the basis for topography. The Anglo-Saxon *grund,* from which we obtain ground, meant 'bottom' or 'foundation,' and surface literally is 'above' the 'face.' From the Latin *libra,* 'a balance for weighing,' we get the word level, the significance being in the positions of the two pans of a balance when their weights are equal. Elevation probably comes from a related source, though it is directly from *levis,* Latin for 'light in weight,' or *levare,* 'to lift,' since what was light could be lifted. Slope is from the Anglo-Saxon *slupan,* meaning 'to slip.' The fragmental rock waste forming a slope at the base of steep cliffs or scarps is known as talus, French for 'slope,' or 'ramp.' Scarp is French for 'sharp,' and ridge is Anglo-Saxon, meaning originally 'the crest of an animal's back,' or 'backbone.' The word hill is from the Latin *collis,* also meaning 'hill,' and illustrates the principal in philology which, rightly or wrongly, has been called Grimm's law.† Jakob Grimm, who was not merely the author of the famous fairy tales but was also an authority on philology, observed in 1822 that many Greek and Latin words having certain consonants appeared in German and English with other but more or less uniformly chosen consonants. The Latin "c" became almost regularly the English letter "h," as *cornu* ('horn') and *collis* ('hill').

Mountain has come down from the Latin *mons* with little change. Marsh is Anglo-Saxon *mere,* in turn derived from Latin *mare* ('sea'). It is another word borrowed from Latin by people living on the continent, and taken by them into Britain in the invasion. A more stiff-necked word is paludal, from the Latin *palus,* meaning 'marsh.' Valley, like mountain and many other words, has come from the Latin *vallis* and Middle English *vale* with little change in form and none in meaning, although in the first source the sense of 'wall' is involved.

River is from the Latin *rivus,* from which in turn the Latin *rivalis* is derived. *Rivalis,* as an adjective, meant 'pertaining to a brook.' The word rival originally applied to neighbors whose property bordered on a stream. The situation developed competition, and from the competition came the name for that form of human behavior known as rivalry. Rivals, therefore, were once merely neighbors along a stream.

The word meander is from the winding river of that name in Phrygia. Cataract is Greek, the roots meaning 'to break down.' The Gaelic word for a wide valley bordered by hills was *srath.* The word, with the letter "t" inserted, is to the physiographer a level valley floor representing a regional base level.

A land area eroded to an extreme, where most of the hills have disappeared and the topography is nearly that of a plain, was named by Davis a senesland, the first part of the word having the same root as senile. In other words, a senesland is an oldland. A local mass of erosion-resistant rock remaining above an eroded plain (peneplain) is a monadnock, named from Mount Monadnock in New Hampshire. When such a region is depressed beneath a sea, the monadnock may be buried in sediments. The hardening of the sediments into rock, the re-elevation of the region, erosion of the recently formed rock, and re-exposure of the ancient monadnock, are all slow steps in the geological process of forming a baraboo, the name for a disinterred monadnock. The name is from the Baraboo Mountains in southern Wisconsin, which were named from an early French trader, Jean Baribault.

The Columbia River plateau in Idaho, Washington, and Oregon consists of deep lava flows that cover the region like a rocky sea, above which high points in the original topography project like islands. Such high points, surrounded by basaltic lava, are known as steptoes, from Steptoe Butte in Whitman County, Washington. The butte was named for a Colonel Steptoe who, in 1858, led troops against the Palouse Indians, with whom a battle was fought in the vicinity.

Ground Water

Ground water hydrology has a large number of technical terms of its own, only a few of which will be considered here. The English word cave is from

† Otto Jespersen, however, credits the Danish scholar Rasmus Rask with the earlier expression (1814) of the law of consonant shift. (Jespersen, *Growth and Structure of English Language,* p. 22.)

the Latin *cavus,* which meant a 'hollow.' The study of caverns is known as speleology, from the Greek word *spelaion,* also meaning 'cave.' The first spouting water obtained by boring a hole in the earth, in 1125, was in the basin in the old province of Artois, now the department Pas de Calais, northern France. In ancient times Artois was known as Artesium, from the Celtic tribe of Atrebates who inhabited the region in the time of Julius Caesar. Geyser is old Norse, probably imitative of the gushing sound made by the erupting hot water. In the vicinity of Laibach, northwestern Yugoslavia, is the region famous for sinkhole topography known as karst. The word karst is from the Slavic *kras* 'rock,' or 'crag.' The rough and desolate land is sometimes referred to as *Karrenfelder,* an Austrian provincialism for 'prisoner's field,' probably an allusion to the wheelbarrows, or *karren,* with which prisoners work in barren surroundings at convicts' tasks. The deep, bowl-like funnels holding what little soil still remains are called *dolinas* from a Slavic word for valley.

Vadose water is that found at a shallow depth, and the word is from the Latin *vadum,* a 'ford, or shallows, in a stream.' Water within reach of drilling or digging is phreatic, derived from the Greek word for well. Gound water percolating through subsurface sand or gravel and following the general course of a surface stream is a thalweg, literally German for 'valley way.' Stalactite and stalagmite are both from the Greek root meaning 'drop,' or 'to collect in drops,' though the words themselves are specialized to mean mineral substance accumulating by the evaporation of drops of water.

Map Terms

Map is from the Latin word *mappa,* originally meaning a 'signal-cloth.' Early maps, especially those of the Romans and Arabs, were drawn with the south at the top. During and following the Crusades, the great reverence for the Holy Land led to drawing maps with east at the top, the top margin being frequently embellished with a pictorial representation of paradise. Until late in the eighteenth century English cartographers marked the eastern margin of their maps with a cross. Because the east side of early maps had such importance, and because the eastern side was the side chiefly concerned in putting the map in agreement with the surroundings, we have the word orient in the sense of aligning with the compass. The word is from the Latin *oriri,* meaning 'to rise,' used originally in connection with the rising of the sun in the east.

Cartography, the science of map-making, is from the Greek *chartes,* meaning a 'sheet of paper,' and the familiar *graphein.* The first root is the direct parent of our word chart, and it might be mentioned in passing that the place where maps are kept on shipboard is still known as the charthouse.

There are many terms qualifying maps or the adaptation of maps for particular uses. There are paleogeographic maps showing the ancient (*paleo*) relations of land and sea, and paleogeomorphic maps, showing the relationship of ancient topographic features. A palinspastic map (*palin,* 'again,' and *spastikos,* 'pulling') shows the original positions of land masses before changes such as continental drift, or extensive diastrophism. There are numerous terms, too, used to describe the detailed parts of maps, or the applications for which some maps are used. Isopach maps (*isos,* 'equal,' and *pachys,* 'thick') are maps on which contourlike lines join points of equal thickness of a given bed or series of rock. Isochor lines (*chora,* 'space') are similar lines joining points of equal vertical intervals between two beds, series, or groups of stratified rocks. Isochlor lines are entirely different, for they join those points where samples have indicated that water in the deep rocks contains equal amounts of chlorine. Isolithic lines connect points of similar rock character (*lithos,* 'rock', and an isothism (*iso* and *othism,* or 'equal' and 'push') connects those points where the horizontal displacement of rocks was equal. Isovols in coal regions connect points where the ratio of the volatiles and the fixed carbon, or 'carbon ratios,' are equal.

Explorers and Settlers

The explorers, *voyageurs,* trappers, and early settlers applied their own terms to geologic features, many of which became embedded in scientific terminology. The word plateau is from the French for 'plate,' 'tray,' 'platform,' or 'pedestal.' The word butte was introduced independently by the French in the Louisiana coastal region and by those roaming the Northwest. From its original sense of 'target,' the meaning was shifted to that of a landmark, and in the latter sense it became specialized in the United States. Prairie, originally an extensive meadowland, came into common use from French traders during America's early colonial days. Rapids is almost the direct French *rapide*; and dalles, applied in Canada and parts of the United States to rapids confined between deep and narrow rock walls, is from the French *dalle,* a 'gutter,' or 'trough.' The French word *coulee* was originally a flow of lava that solidified to form a ridge or crest

on the flank of a volcano, derived from *couler,* which means 'to flow.' In the northwestern United States the term is applied to a steep-sided gulch or trenchlike gorge.

The Spanish gave us mesa, meaning 'table,' and canyon which comes from the Latin *canna* ('reed'). Arroyo basically is a 'gutter,' but it is interesting to note the difference in the mental image—all due to climate and topography where the original explorers applied the terms—between arroyo and dalles, although in source both have almost identical meanings. A playa is a shallow basin in a desert where water is impounded briefly after a rain, but which dries rapidly by evaporation. The word is Spanish for 'beach,' or 'shore.' Those saucer-shaped playas containing water, or containing only the solids deposited by water, are known as bolsons, meaning 'pockets.' The alluvial slope flanking mountains and leading down to the mud flat of the playa is a bajada, Spanish for 'ladderway,' 'path,' or 'slope.' Tilted beds of rock forming ridges with a sharp, clifflike face on one side are cuestas, meaning 'slope,' or 'grade,' but in the original sense having the meaning of 'shoulder.' Barrancas are radial corrugations on volcanic cones resulting from mud flows and their erosive effects caused by the steep gradient. In southwestern United States an isolated hill of older rock surrounded by younger sedimentary deposits is an *huerfano,* a Spanish word for 'orphan,' and a particularly apt term.

In New Mexico and Arizona a *charco* is a waterhole, a *picacho* is a sharply pointed hill, and a *rincon,* from the Spanish for 'inner corner,' is a cove, or entrant, along the face of a mesa. Almost any porous material such as gravel, cemented by calcium carbonate, is known as *caliche.* The Spanish word originally was used for a small stone or pebble accidentally burned with the clay mass when brick or tile was made, and it also was used for a crust of lime or similar material flaking from a wall.

The sandy spit tying an island to the shore is known as a tombolo, a good example being that extending from Nahant Island, Massachusetts. The word was probably given by Italian or Portuguese fishermen, the original meaning a 'cylindrical cushion,' or 'bolster.'

The Ojibway Indians are supposed to have given us muskeg, their original being *mashkig* or something similar, meaning 'bog' or 'marsh.' McGee adopted the word paha from the Dakota Indians. Apparently the same form was used in both singular and plural for the low, elongated glacial hills, covered with a veneer of loess, found in northeastern Iowa.

Blends

Those terms known as blends, formed by combining syllables, or sometimes by merely joining letters of two or more words, are occasionally found in geology as they are in other sciences. Nonscientific illustrations are brunch (breakfast and lunch) and smog (smoke and fog). Many years ago, the writer heard a guide at Mammoth Cave describe the growth of a stalactite and a stalagmite. "Often," he commented, pointing to an example, "the two join in a pillar—and that is a mighty-tight!" This grim blend may have been old then, and it is heard even today after being handed along from guide to guide for many years. It has not (fortunately) become a part of the geologist's accepted vocabulary, though it must be admitted other blends, almost as weird, have.

In the matter of genealogy of words, blends may be difficult but, once established, they are specific in meaning. As an illustration of specific application one might take the term fanglomerate, proposed in 1913 by Lawson for the coarse deposits at the head of an alluvial fan and later consolidated into a conglomerate. Lawson combined a part of the word conglomerate, long used for rounded rocks cemented as an aggregate (*con* and *glomus,* or 'ball'), and the 'fan' of alluvial fan. The same geologist coined the words 'kernbut' and 'kerncol.' The first syllable in each is from Kern Valley, California. Faults along the flanks of mountains in Kern Canyon produced prominent benches. The knifelike ridge of the bench, more or less paralleling the mountain, is the kernbut, from *Kern* and *buttress.* The trough where the faulted block joins the mountain is the kerncol, the last syllable from the French *pass* (in a mountain), in turn from the Latin *collum.*

Suess gave the term sima to the deeper rock masses, including those beneath the ocean basins, which average about 3.1 in density. This is a blend of the first two letters of silica and magnesia, the minerals predominating in deeper plutonic rocks. The lighter continental masses consisting chiefly of silica and aluminum and having a density of approximately 2.7, he named sal, from the initial letter of silica and the first two letters of aluminum. At Wegener's suggestion, this word was later changed to sial to avoid confusion with the Latin for salt.

The blends cubem and cubek have been used in petroleum geology to designate the oil content in barrels per cubic mile and per cubic kilometer of sedimentary rock. It is doubtful if any of

these terms would be understood by one who met them for the first time.

Stilted Terms

When geology as a science first started to develop specialized branches, concern was expressed from time to time over the use of seemingly unnecessary new words. One geologist protested in 1897 against the tendency toward the multiplicity of additions to the geological lexicon. He cited the word monadnock as an example, with the comment that few would recognize it as a geological term, though a great many people would know it either as the name of one of the large buildings in Chicago or as a ship in the U. S. Navy. It is a matter of doubt whether very many residents of Chicago could readily locate today's Monadnock Block in that city. Certainly the name of the ship is past all ordinary recollection. Yet today no geologist regards the word monadnock as either unnecessary or as a poor choice.

There is always a tendency, on the other hand, to propose a few terms because they appeal to individual fancy, or because they have the appearance of being technical. If such a new word happens to have as a competitor a simple and virile synonym, the newcomer does not survive. In 1902 the Dutch word *geest* was revived (it had originally been proposed by DeLuc in 1816) as a replacement for the term mantle rock, and about the same time, the word regolith was proposed. *Geest* failed from the outset to be accepted, and regolith has never been widely used. The term mantle rock is made up of two old and entirely understandable words, and the combination forms a fully descriptive expression. Regolith, derived from *regos* ('blanket') and *lithos,* although still used to some extent, is not only artificially pretentious but is an exact duplicate, in fancy dress, of the word it would displace. Eolation, meaning gradational work performed by the wind, is another suggestion that failed to come into general use.

It is undoubtedly true that most technical words have the ring of bombast when they first are heard. The word geology itself must have seemed a stilted word when it was first used in its present sense in 1661.‡

‡ According to Frank D. Adams (Earliest Use of the Term Geology. *Geol. Soc. Am. Bull.* 43, No. 1, 121), the word was first used by Richard de Bury, Bishop of Durham, in his book *Philobiblon,* printed at Cologne in 1473. He used the term for the study of law, the "earthly science." Robert Lovell, in his *Universal History of Minerals,* published at Oxford in 1661, was the first to use the word in its present sense.

Orogeny (Greek *oro,* 'mountain,' and *genos,* 'birth') for mountain building, and Gilbert's epeiorgenic (*epeioros,* 'mainland,' and *genos*) for the broad, warping uplift of larger areas of the earth certainly possessed a learned appearance when first used. Palingenesis, the reversal of a geological process, such as remelting of solidified igneous rock, comes from the Greek *palin* ('again') and *genos.* This word, it might be said, was originally a biological term used by Haeckel.

Hans Stille has given us a number of new words with uncertain survival potential. A craton (*kratos,* 'power,' 'strength') is an area of rocks that has remained relatively immobile while areas adjacent were depressed to form synclines. A hedreocraton (*hedreo,* 'stable,' 'steadfast') is a craton persisting without structural change through long periods of time. A miogeosyncline (*mio,* 'less') is the structural trough located near enough to the hedreocraton so that material eroded from the latter was deposited in the trough. The eugogeosyncline (*eugo,* 'true,' 'actual') is further removed from the hedreocraton, is usually deeper, and contains deposits from other sources. Kay has given the more specific terms exogeosyncline (*ex,* 'outside') for the synclinal structure touching the craton, but containing detritus obtained from sources other than the craton. He has named many other specific features—zeugogeosyncline (*zeugo,* 'yoke') traphogeosyncline (*trapho,* 'trench'), a geosynclinal tract bordered by prominent faults, and paraliageosyncline (*para,* 'beside,' and *hals,* 'sea') for a geosyncline along the margin of a continent.

Words, as someone has said, epitomize concepts. Like many things in the physical world, they go through an evolution from simple to complex, and sometimes they complete the cycle by breaking down from the complex to the simple. The scientific vocabulary may seem unreasonably high-sounding to the so-called practical person, until he attempts to translate a single technical term into ordinary language. Our everyday conversation is full of technical expressions that have become commonplace with use, and that, were they not widely used and as widely understood, would necessitate a veritable wilderness of words in their place. Imagine trying to impart the simple information that today's temperature is 85° to one who, though fully versed in basic English, does not know what a thermometer is, or how it is graduated, or what the different types of thermometers are. Without the proper word, simple things are truly complicated!

Organized Research in the USSR

I. S. SOKOLNIKOFF

The author, who was born in Chernigov, Russia, in 1901, became an American citizen in 1927 and took his Ph.D. at Wisconsin in 1930. He has been a consultant to the Army Air Force, technical aide in the applied mathematics panel of the Office of Scientific Research and Development, and, since 1946, professor of mathematics at the University of California at Los Angeles. He was awarded the Presidential Certificate of Merit for contributions to the war effort of the United States and its allies in World War II. Dr. Sokolnikoff specializes in the mathematical theory of elasticity and boundary value problems.

IT IS obvious that none of us, even the man on the street, needs to be convinced of the value of research. The evidence of the extent to which scientific research permeates our lives is all around us. The American public has been most generous in providing both financial support and recognition of the mixed blessings bestowed on it by research. We are now on the threshold of new and momentous developments in organized research to be sponsored by the public. Recently our press carried the news that President Truman had signed a bill setting up a National Science Foundation to promote research and education in the basic sciences. He recognized that the establishment of the foundation is a major landmark in the history of science in the United States and that our ability to survive and grow as a nation depends to a very large degree on our scientific progress.

I would like to share some of my views on organized and planned research, as distinguished from individual research, and to indicate the role of the government of the USSR in the sponsorship of organized research, which may find some parallels in the development of government-sponsored research in the USA.

First of all, I should like to make the observation that in many sciences individual research is being displaced by the research of organized teams of investigators working on groups of closely related problems. By individual research I mean the research of a professor who works on isolated problems in his spare moments free of teaching and committee work. Organized research, on the other hand, I take to mean a planned activity by a group of individuals who consider research not as an incidental pleasure performed after hours but as their main job.

The spectacular growth of research institutions since the war, and the organization of research in such large departments as chemistry and physics, are among the most obvious evidences of the trend away from individual research. There is little doubt that this tendency was accelerated by the wartime experience of our scholars with the work of the Office of Scientific Research and Development and the Office of Strategic Services, and by the subsequent connection of scientists with the work of the Atomic Energy Commission, the Office of Naval Research, and various other research agencies of the Department of Defense.

There are fears, mostly among those who are not too familiar with the spirit in which the government-sponsored investigations are conducted, that organized research may lead to regimentation and the stifling of individual initiative. There are even greater apprehensions as to what the National Science Foundation may do to free enterprise in research. I do not happen to share these fears, because I do not think that scholars offer a suitable material for regimentation. I believe that the danger, if there is any danger, is the other way around. In the long run scholars are more likely to "regiment" the government than the government is to leave its imprint on scholars. We may find an account of the experience of the USSR Academy of Sciences in this area interesting and to the point. There are curious parallels in the role that our own National Academy of Sciences in Washington has played in furthering government participation in the scientific life of the country and a similar role of the Russian Academy of Sciences in the growth of science in the USSR.

Although the facts about the National Academy

* Based on the initiation address for the University of California (Los Angeles) Chapter of Sigma Xi, May 1950.

of Sciences are familiar to most of us, let me recall them in order to emphasize the similarities in the pattern of development of government-sponsored research in the USSR and in this country. (Perhaps before I go further I should state that I am neither a Communist nor a member of any party that advocates the overthrow of the United States government by force. What I shall have to say appears to have no connection whatever with political philosophies or forms of government.)

The evolution of government-sponsored research in this country can be traced to the establishment by the Congress of the United States, in 1863, of the National Academy of Sciences. The act of incorporation of the Academy specifies that ". . . the Academy shall, whenever called upon by any department of the Government, investigate, examine, experiment and report on any subject of science or art. . . ." The actual participation of the academy in the formation of the scientific policies of the government up to 1916 was fairly nominal. The academy consisted of a body of distinguished scholars who no doubt moulded the scientific thought of the country, but when I speak of nominal participation I have in mind direct participation in the formation of policies. In 1916 President Wilson requested the academy to organize, as a measure of national preparedness, the National Research Council. This temporary organization proved so effective that the President issued an Executive Order requesting the academy to perpetuate the council and to broaden its base for service. In effect, the academy, through the National Research Council, became an advisory and, by indirection, a policy-forming body on diverse matters of science. In 1941, for example, it played a critical role in the establishment by President Roosevelt of the Office of Scientific Research and Development. It is also quite likely to become the guiding arm of the National Science Foundation.

The Russian Academy of Sciences is considerably older than the National Academy. It was established early in the eighteenth century, with similar but somewhat broader purposes than those of our National Academy. Although the law establishing the National Academy mentions art, the activities of the academy have been confined almost exclusively to the field of natural sciences. The Russian Academy, on the other hand, spreads over the entire spectrum of learning, including the social sciences, jurisprudence, literature, and music. Prior to World War I it exercised a strong influence on the development of higher learning in Russia. Its advice was frequently sought by the Russian government, since most institutions of higher learning in Russia were subsidized by the government, but it did not operate directly any research institutes or laboratories. As elsewhere throughout the world, research activities in Russia were largely the after-hour efforts of tired professors. In the past thirty years the pattern of activities of the Russian Academy has been radically changed, and it has become not only an advisory and policy-forming body on matters of learning, but also the most important operating agency for the huge amount of organized research done in Russia. It formulates the plans for operation of many institutes, laboratories, museums, and art galleries that are under direct supervision of the academy. Recently —that is, during the past ten years or so—it has become, through its numerous research institutes, the leading participant in the creation of new industries, and even in the actual operation of industrial plants. As an example I might cite the Institute of Optics, which supervises the production of optical glass in the USSR. This trend is interesting in that it might eventually lead to a complete dominance of industry by the Academy of Sciences and hence of the economic life of the USSR.

Some years ago I became interested in the role of the Russian Academy of Sciences in shaping the economic life of the Soviet Union and attempted to piece together whatever information I could gather from scientific journals and published reports about the deliberations of various scientific bodies in Russia. This information cannot be obtained by dropping a penny postal card to the appropriate government printing office. During the past five years it has been especially difficult to obtain a rounded picture of what goes on in Russian science because the flow of scientific literature to this country has been considerably curtailed. But I believe that I have a fairly accurate picture up to 1944, and by extrapolation one can guess what may have happened in the past five or six years.

It may be well to begin by describing the structure of the academy in 1944. The USSR Academy of Sciences is a self-governing body of distinguished scholars drawn from all fields of arts and sciences. Considering the range of scholarship it covers, its membership is very small and highly selective. There are two grades of membership: active membership, and a sort of associate, nonvoting membership called corresponding membership.

In 1943 there were only 117 full members and 168 corresponding members in the Academy. These were distributed among eight divisions, as shown in Table 1.

TABLE 1

	Members Elected in 1944	
	Full	Corresponding
Physics–Mathematics	6	9
Chemistry	3	12
Geology–Geography	4	5
Biological Sciences, including Medicine	3	5
Technical Sciences (Engineering and Technology)	8	10
History–Philosophy	4	9
Social Sciences and Law	2	3
Literature, Language, and Music	6	5

I was unable to get an accurate picture of the distribution of members among these divisions, but the relative emphasis or influence in these fields can be surmised in part from the elections of new members in 1944. In 1943 the work of the academy became so broad and varied that it was decided to bring in new blood. To this end, 700 candidates were named for membership. Of this group of nominees, only 36 were elected to full membership and 58 to the nonvoting corresponding membership. The distribution of newly elected members by divisions is indicated in the columns on the right in the list of divisions.

Thus in 1944 full members numbered 153, and corresponding members 226. This group of scholars elected its own executive committees, formulated scientific policies of the country, and directed the research activities of at least 76 scientific institutes, 11 laboratories, 42 experimental stations, 6 observatories, and 24 museums. The staff in the institutions guided by the academy was in excess of 5,000 research workers. The organization and activities of the institutes are a story in themselves that would require much space to describe. I will mention only that many institutes are directed by the academy members who are scholars of first rank. The institutes are planned along bold lines, forming new approaches to research in such overlapping fields as biogeochemistry, physical chemistry, biophysics, geophysics, technological physics, and so on. They publish their own journals, books, and scientific monographs.

I must mention that not all scholarly activities in Russia are directed by the Academy of Sciences. There are numerous university and industrial research laboratories operating outside the sphere of the academy. The number of such in 1943 was well over 1,000. But it is certain that by indirection the academy sets the tone for all scholarly work to be done in the country, and even suggests that certain activities, proposed for development within the academy's structure, be placed in such and such an institute outside the academy.

Now let me indicate, briefly, the specific plans formulated by the academy for 1944. I pieced these together mostly from addresses made by various members of the academy at the General Sessions held in Moscow on September 25–30, 1943, and again in Leningrad on February 14–17, 1944.

The spirit in which the plans were laid down and the outlook on the future are so revealing that I would like to quote some excerpts from a keynote address made by the vice-president of the academy, A. A. Baikov, a distinguished metallurgist. This address was made in September 1943 at the session of the academy devoted to the preparation of basic plans for scientific work in the USSR in 1944. In order to make the quotations meaningful, let us go back to the late summer and early fall of 1943. At that time we were in the midst of war. Basic research in this country was at a virtual standstill, and American scientists were concerned with the day-to-day problems raised by the war. It was several months before General Eisenhower was appointed Supreme Commander of the Anglo-American invasion forces. The Germans had launched their V-bombs, and before the news could be verified, some of us thought that the Kaiser Wilhelm Institute might have stolen a march on the Metallurgical Laboratory in Chicago. The Germans were deep in Russia, and on the day the sessions of the academy opened in Moscow Russian troops recaptured Smolensk. This city, it will be recalled, is only some 200 miles southwest of Moscow. This was the atmosphere and the time of the meetings in Moscow.

Baikov's speech is remarkable for its absence of deification of Stalin. It is sober, and imbued with confidence that the tide has turned and the time has come for making specific plans for reconstruction. Accordingly, he proposed that in 1944 the academy's plans for scientific work in Russia be grouped in three categories. The first of these should naturally consist of matters related to defense and mobilization of resources so that the Red Army would be properly supplied. In the second category he placed the solution of problems concerned with the reconstruction of the territories freed from the enemy, which were to be tackled from a broad point of view that took into account the economics of the entire Soviet Union and its role in the postwar world. But, considering the time, the most remarkable category of all is the third, and on this I should like to quote from Baikov's address. He says:

In the third category belong those directions which are determined by the essence of knowledge itself and which touch upon the profound study and detailed solution of basic scientific problems. One should never forget that science is eternal, and the immediate and pressing problems should not displace the broad and important long-range problems which, at this moment perhaps, have not received sufficiently wide development and application, but which may yield completely new and unexpected significant discoveries. The importance of such discoveries at this time cannot be foreseen, but in the future they may enable us to fathom more deeply and fully the secrets of nature.

One should remember that science can forge ahead, be deepened and perfected only if scientific investigations go on without interruption. . . . For this reason, it is essential that in formulating our over-all program we give attention to important, basic, and leading problems of science.

Baikov then indicates some basic problems in physics that should receive attention. Among these he lists investigations in the domain of extremely high temperatures and pressures, the researches of the Physical Institute in Moscow, headed by P. Kapitza, on extremely low temperatures and the superfluidity of helium, and investigations in the field of atomic physics. Incidentally, about these he remarks, "The problem of atomic nucleus now receives the supreme efforts of the entire scientific world, and its importance requires no elaboration." He also refers to the urgent need for extending our knowledge in the field of the physics of solids and in the preparation of materials capable of withstanding temperatures in excess of 4,000° C. He has in mind, I presume, such materials as the carbides of tantalum.

As I have already mentioned, the purpose of the session in 1943 was to prepare the basis for the over-all plan and to establish the order of priority for various problems. Accordingly, the jobs were assigned to various subcommittees, the divisional committees were to incorporate the plans of subcommittees into divisional plans, and the latter were finally to be merged into an over-all plan involving all eight divisions of the academy.

This over-all plan was the subject of discussions at the February 1944 sessions of the Academy held in Leningrad.

From one sentence of the address delivered by the secretary of the academy, N. G. Bruevich, one concludes that two plans were prepared, one of which is open. Neither of these was made available to me. But the essential features of the open plan are clear from Bruevich's address and may be summarized as follows:

1. The emphasis of all research agencies under the academy's supervision was placed on basic scientific and technological problems.
2. Problems of reconstruction of liberated regions, and of the country as a whole, received considerable attention.
3. The research program was distinguished by the depth and breadth of formulation of basic problems to be considered by the academy. Special problems were to be dealt with by the institutes outside the academy.

In order to indicate the range of problems, I list the topics proposed for investigation by several divisions:

Physics–Mathematics

1. Studies in atomic physics and cosmic rays.
2. Investigations in temperature near absolute zero.
3. Study of mechanical properties of polymers and anisotropic media.
4. Development of the theory of stability of solutions of partial differential equations.
5. Development of a statistical theory of mechanics of continuous media.

Economics–Law

1. Researches in the history of economic thought.
2. Investigation of problems of international law, with particular reference to postwar settlement.

Technical Studies

1. Theoretical investigations of deformation and stresses in shells of small and medium thickness (aircraft and submarines).
2. Research in stability of motion of mechanical systems.
3. Servomechanism theory.

Chemistry

1. The development of theories of chemical bonds and physicochemical analysis of metallic and organic systems.
2. Kinetics and catalysis of chemical reactions.
3. Chemical transformation under extremely high pressures.
4. Theoretical questions connected with electrolytic processes.
5. Research in complex reactions and radioactivity.
6. Work on synthesis of hydrocarbons, and metallo-organic and heterocyclic compounds.

Geology–Geography

1. The basic problems of stratigraphy and tectonics of the USSR.

2. The theory of formation of coal and the earth's core.

3. Study of the basic problems connected with the mineralogy and geochemistry of pegmatites and rare elements.

4. Geographic and geological surveys in countries adjoining the USSR.

5. Construction under conditions of permanent frost.

Biological Sciences

1. Stress on the fundamental problem of biology —the problem of Darwinism.

2. Research on albumens and ferments.

3. Problems concerned with epidemiological diseases. Rodents and other carriers of infectious diseases, with emphasis on the problems of parasitology and sanitation.

4. The expansion of food resources. Increase in soil productivity and cattle breeding.

Naturally, I was in no position to trace out the execution of these plans in fields outside my specialty. But the progress in that connection is remarkable, and it is safe to say that in the past five years more significant work has been done in the fields of elasticity and plasticity in Russia than in all the rest of the world combined. This can be explained, in part, by the fact that Russia was preeminent in these fields prior to World War II, but, even with that taken into account, the influence of planned research on the volume and quality of productivity is remarkable.

Before I conclude I should like to say a few words about the way in which the Russian plans for scientific research are formulated. The impression that one might get by drawing the analogy with politics is that scientific plans in Russia orginate with some supreme committee of scientific czars. This does not appear to be the case. The individual workers in the institutes and laboratories throughout the USSR are invited to submit their plans for the work in their own institutes. These plans are examined, debated, and revised by the research committees in charge of the work of that institute. Ultimately they are passed on to the appropriate division of the academy, where they are collated and debated by the academy members and by the research council of the division concerned. Ultimately, divisional plans are formed, studied by the Executive Committee of the academy, and incorporated in the over-all plan. From published accounts, at least, it appears that in scientific matters they follow a committee system not unlike that used in many American universities. One might wish that the system would be extended to other fields of human endeavor in Russia, but that is obviously wrought with complications for the Communist dictatorship.

My kingdom is as wide as the world, and my desire has no limit. I go forward always, freeing spirits and weighing worlds, without fear, without compassion, without love, and without God. Men call me Science.

—Gustave Flaubert, *Lamentation de Saint Antoine* (1874)

Cork, Bark of the Exotic Quercus Suber

GILES B. COOKE

Giles B. Cooke directs the research and development work on cork and rubber products in Crown Cork and Seal Company's Research Department. He is a graduate of the College of William and Mary and took his Ph.D. in organic chemistry at the University of Maryland in 1929. For the past twenty years Dr. Cooke has been actively engaged in research on cork, cork products, and rubber compounds, and a number of patents have been issued on his developments in these fields. He is the author of more than sixty technical and educational articles about cork and rubber.

CORK is the bark of the cork oak tree, *Quercus suber,* which is indigenous to those countries that form the shores of the western Mediterranean. Portugal, Spain, France, and Italy in Europe and Algeria, and Morocco and Tunisia in Africa, are the cork-producing countries of the world. For more than 2,000 years all the cork for the world's commerce has come from different sections of these countries. The greater portion of the cork forests, which cover approximately an area the size of the state of Connecticut, a total of about 5,000,000 acres, is of natural origin. Here for centuries cork forests have withstood the ravages of wind, fire, war, and other destructive forces. Only in comparatively recent years has special attention been given to the care of these important areas.

Historical Review

Cork is a very old plant product measured in years of service to mankind. One of the old written records of its use dates back to about 400 B.C., but without doubt this light thick bark was used many centuries earlier. Natives in the cork-producing countries have from the earliest times used cork bark to serve their various needs. Just what the early people of the Iberian Peninsula thought of cork 3,500 and 4,500 years ago and how they used it would make interesting reading. It is fascinating to speculate and safe to guess that cork was employed then for some of its present-day applications.

The early Greeks and Romans were familiar with cork, and in the classic works of ancient and medieval writers numerous references to it can be found. Plutarch (A.D. 46–120), in his famous *Parallel Lives,* II, XXV, 154, *Life of Camillus* (Marcus Furius Camillus, 446–365 B.C.), tells of the use of cork as an aid in swimming. When Rome was besieged by the Gauls (*ca.* 400 B.C.), Camillus was named dictator, and it was necessary to obtain the approval of the Senate, the members of which were imprisoned in the Capitol. A youth, Pontius Cominius, volunteered to carry the message, and as the bridge across the Tiber was guarded by the enemy, he swam the river at night. We read:

> But there was a certain young man, Pontius Cominius by name, who was, in spite of his ordinary birth, a lover of glory and honour. He volunteered to attempt the task. He took no letter with him to the defenders of the Capitol, lest this, in the event of his capture, should help the enemy to discover the purpose of Camillus; but under the coarse garments which he wore, he carried some pieces of cork. The greater part of his journey was made by daylight and without fear; but as night came on he found himself near the city. He could not cross the river by the bridge, since the Barbarians were guarding it, so he wrapped his light and scanty garments about his head, fastened the corks to his body, and thus supported, swam across, came out on the other side, and went on towards the city.[1]

Pliny the Elder (*ca.* A.D. 23–79), gives a detailed description of the cork tree and its utilization in his famous *Naturalis Historia,* XVI. In Section 13 he writes that it is a small tree with evergreen leaves, bearing small acorns, and he further states:

> Its only useful product is its bark, which is extremely thick and which when cut grows again; when flattened out it has been known to form a sheet as big as 10 feet square. This bark is used chiefly for ships' anchor-drag ropes and fishermen's drag nets and for the bungs of casks, and also to make soles for women's winter shoes. Consequently the Greek name for the tree is "bark-tree," which is not inappropriate.[2]

Other famous Romans also wrote about cork,

telling of varied uses for the material. Horace (65–8 B.C.), in his classic works, refers to wine casks being sealed with cork. The Romans in the process of aging wine subjected casks to smoke and, according to custom, dated the wine and recorded the name of the Consul on the cask. In Horace, *Book III*, Ode 8, we read:

Hic dies anno redunte festus
Corticem adstrictum pice dimovebit
Amphorar fumum bibere institutae Consule Tullo.
("This day, sacred in the revolving year,
shall remove the cork fastened with pitch
from that jar, which was set to inhale the
smoke in the Counsulship of Tullus.")[3]

Columella (about A.D. 20–75) referred to cork in the making of beehives. In an English translation we read: . . . "Bee-hives must be fabricated according to the condition and circumstances of the country. For if it be fertile of the cork-tree, without any doubt we may make very useful hives of its bark, because they are neither extremely cold in winter, nor exceedingly hot in summer."[4]

Theophrastus (372–287 B.C.) was the first Greek author to describe the cork oak. In his famous work on botany, he wrote:

Some, however, are more local, such as the cork oak: this occurs in Tyrrhenia: it is a tree with a distinct trunk and few branches, and is fairly tall and vigorous growth. The wood is strong: the bark very thick and cracked, like that of the Aleppo pine, save that the cracks are larger. The leaf is like that of the manna-ash, thick and somewhat oblong. The tree is not evergreen but deciduous. It has always an acorn-like fruit like that of the aria (holm-oak). They strip off the bark, and they say that it should all be removed, otherwise the tree deteriorates: it is renewed again in about three years.[5]

It's corking time in Portugal. A cork forest near the Rio Frio 25 miles from Lisbon south of the Tagus River. The cork forests resemble orchards, so meticulously are they planted and so carefully cultivated is the ground between trees. It is not rare to see trees several centuries old, which attest to the favorable climatic conditions of the country for this crop.

This description of the cork oak by Theophrastus is in general correct. In its natural environment the leaves of the tree are green during the winter and remain so several seasons. Some cork oak acorns are small, but from the large, scattered old trees they are of good size and resemble acorns of the white oak, *Q. alba*.

Theophrastus describes the cork tree and referred to the hard outside portion of the bark. He does not discuss cork and its applications, but the Greeks were familiar with its characteristics and made practical use of this unique bark. Pausanias, traveler and geographer of the second century A.D., in his Report VIII, referring to the oak trees of Arcadia, wrote:

The oaks in the groves of the Arcadians are of different sorts: some of them are called "broad-leaved," others "edible oaks." A third kind have a porous bark, which is so light that they actually make from it floats for anchors and nets. The bark of this oak is called "cork" by the Ionians. . . .[6]

For many centuries cork has been employed to keep heat in and keep it out. The natural cork bark served this purpose in medieval times. Early monasteries were provided with cork-lined walls and ceilings to provide protection from the intense heat of the summer sun. Peasant natives in the cork-producing countries for centuries used cork slabs to roof their houses and to provide soft floors that were always warm to the touch. In later times cork was mixed with earth and used to form the walls of buildings.

With the invention of the glass bottle in the fifteenth century and its more general introduction in the seventeenth century, the use of cork became more widespread and the cork industry may be said to have started then. Cork forests that had been growing wild for centuries were recognized to have a definite commercial value. The first steps toward the cultivation of the cork oak tree were taken in Spain in 1760. A German who had taken up his residence on the Spanish peninsula rented several cork forests, cleared away the undergrowth, and supervised the harvesting of the bark. The cork was exported to Germany and sold there. Others, recognizing the profit to be had in such an enterprise, followed his example and by 1830 the cultivation of the cork oak had extended into France, Portugal, Italy, and northern Africa.

Later, cork was used to make barricades on English naval vessels. In Samuel Pepys' diary, we read:

July 14, 1666

That being done, I down to Thames-streete and there agreed for four or five tons of corke, to send this day to the fleete, being a new device to make barricados with, instead of junke.[7]

Growth and Harvest

Cork is the outer bark of the cork oak tree. There are several varieties of the cork oak, the two best known species being *Q. suber* and *Q. occidentalis*. Both these species are evergreen and have perennial foliage. They differ very slightly, but *Q. occidentalis* is more resistant to cold weather. The cork oaks are not large trees; they measure 9–15 feet around the trunk and attain a height of 35–60 feet. In general appearance the cork oak resembles the live oak, *Q. virginiana*. The leaves are similar in form and color to the holly leaf but are soft and smooth to the touch. The roots are spreading and often may be seen above the surface of the soil. In May and June the yellow blossoms come out, and in the fall the acorns ripen.

Cork oaks live for about one hundred and fifty years, although some trees have been known to survive for two hundred to three hundred years and even longer. The outer bark requires eight to ten years for growth; annual rings are formed in the cork bark just as in the wood, and the years required for the growth of a specimen of cork can be determined by counting the number of these rings. Soil and climatic variations affect the growth of cork, and these differences can be observed in the varying widths of the annual rings.

When the tree is about twenty years old, or 9 inches in diameter, the bark is ready for the first stripping. This cork is known as "virgin cork" and is of inferior quality. The bark is removed at eight- or ten-year intervals thereafter, depending upon the growth and demand, and it is with the third stripping that the first good-quality cork is obtained. Thus, thirty-five to forty years pass in the life of the cork oak tree before it reaches the profitable commercial stage. For this reason it is easy to understand why the greater part of the world's cork forests are of natural growth. The long period of time required to bring them to productive maturity, during which the cork oak yields little or no profit, discourages the planting of the trees by individuals and private corporations. Nature has assumed the responsibility for the propagation of the cork tree and has fulfilled this self-imposed obligation remarkably well. In recent years, however, the Portugese, Spanish, and French governments have aided in the development and extension of their respective cork forests.

Cork readily separates from the trunk of the tree, and expert strippers remove the bark in large pieces.

Cross section of trunk of a young cork oak. Note the inner bark between the cork and the wood.

Stripping of the bark is carried out during the summer months. Hot weather followed by rain facilitates the removal of the bark, and a general rule is that it should be done when the sap is flowing freely. The sap does not flow through the cork; consequently it can be removed without danger to the tree. Care must be taken, however, not to cut the inner bark, for if this is seriously injured the tree will bleed and possibly die. Cuts are made around the trunk near the ground and just below the first branches, and, making use of the natural voids, the bark is carefully pried away. Care is taken to keep the bark in slabs as large as possible, for small pieces bring lower prices. The actual

stripping is usually done by skilled workmen, and untrained laborers bundle the cork bark and load it onto the backs of burros or into carts drawn by oxen; motor trucks are employed to a limited extent. In many places the larger branches are also stripped, but in Morocco the French government limits the stripping of cork to the tree trunk. Large forest owners divide their property into tenths and strip a section each year. In this way the laborer receives continuous employment, and the owner has an annual income from his cork groves.

The bark varies in thickness, and the yield per tree ranges from twenty-five to several hundred pounds. Depending on the number of trees per acre and the yield per tree, a skilled stripper can gather 300–750 pounds of corkwood in a day. The stripped bark is hauled to designated central stations, where further operations prepare it for baling. The cork is stacked and left to season for a few weeks. This curing period allows excess moisture to evaporate and aids in flattening the curved bark. The cork bark is then boiled in big copper tanks, large bundles of the bark being lowered into the boiling water by means of a block and tackle. Heavy weights keep the cork submerged for about thirty minutes. The boiling process removes tannins, any other water-soluble materials that might be present, and loose dirt. Also, the cork is softened, and the rough, hard outside portion, known in the trade as "hardback," is loosened so that it can readily be scraped off after the cork is removed from the vats. Hoe-shaped knives are employed for scraping away this outer portion, which amounts to 2–3 per cent of the volume of cork bark and 15–20 per cent of the weight. An average day's work for a man skilled in the scraping operation is said to be 450–600 pounds per day.

Structure and Physical Properties

Cork is composed of tiny cells, and under high magnification this characteristic cellular structure can be seen. The cells vary in size, and number about 200 million to the cubic inch. They are filled with air and are held together by a resinous adhesive.

Lewis[8] has shown that the cork cell possesses 14 sides, 6 of them being quadrilaterals and 8 of them hexagons. This formation is due to nature's method of giving the cells the greatest possible volume with the least amount of surface, while permitting the cells to form a compact unit.

Cork is compressible and resilient, and these

Hauling cork to a boiling station. Although the cork is piled high, the load is not heavy.

properties enable it to give a perfect seal when used as a crown cap liner. Each tiny cork cell functions as an air cushion, permitting the crown cap to be pressed firmly against the mouth of the container and constantly exerting a back pressure, thus making a tight and permanent seal. Cork is very light, its specific gravity being about 0.20. The lightness is due to its air-filled cells. This property of cork gives it many applications where floats and articles of low density are required.

Both the air-filled cork cells and the natural adhesive that holds them together are impervious to water. This property gives cork many applications where a water-resistant material is required. Cork is oil-resistant, also, and on account of its noncapillarity, which results from its cellular structure, penetration of cork by liquids in general is extremely difficult. For this reason cork is used as a bottle closure for innumerable solutions and liquids.

One of the best thermal insulators known is air in finely divided spaces. The tiny air spaces in cork are responsible for its heat-insulating properties. The thermal conductivity of cork is low, and corkboard is an excellent material for low-temperature insulation. This property, together with its lightness and resistance to moisture penetration, makes corkboard an ideal insulator for refrigerators, cold storage rooms, and air-conditioned buildings.

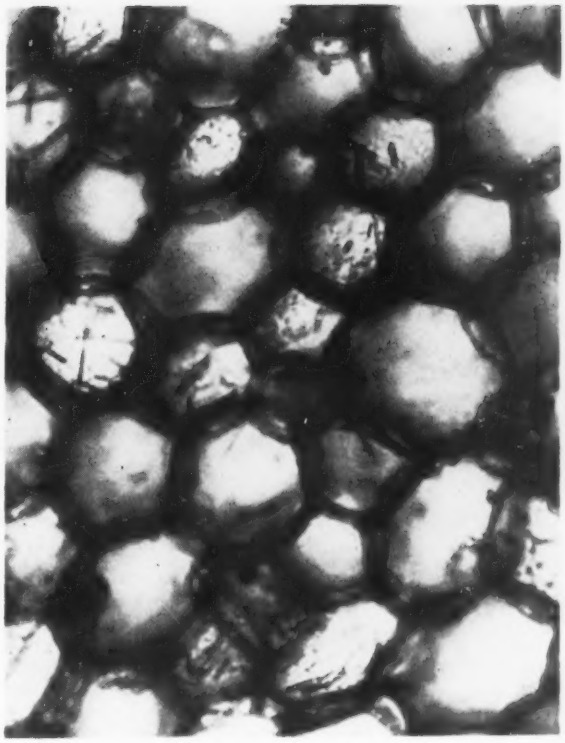
Vibration and wear are greatly reduced by mounting machinery on cork. Sudden pressures and shocks cause the air-filled cells to quickly compress, and the vibrations are not transmitted through the cork. The air-filled cells also give cork an important place in the modern building industry. Corkboard is used to insulate against outside noise and to absorb sound formed within and prevent echoes. Radio and motion-picture studios have found that the use of cork results in excellent acoustical conditions.

Cork possesses a relatively high coefficient of friction. When it is sliced, many of the cells are cut and thousands of microscopic cups are formed on the surface. In these cups partial vacuums are formed when cork is drawn over a smooth surface. This accounts for its high friction coefficient and for its use where a material of nonslipping character is desired.

These physical characteristics of cork, together with its chemical stability, are responsible for its many varied applications.

Chemical Properties

For centuries the stability of cork has been an outstanding chemical characteristic and has made it suitable for many diversified applications. Clean



Cork cells (×600.)

cork of commerce is not affected or changed in composition by contact with water, vegetable, animal, or mineral oils, gasoline, many organic solvents, and many gases, such as carbon dioxide, hydrogen, nitrogen, and air. Cork is highly resistant to fruit and vegetable acids, hydrochloric acid, many organic acids, soaps, mild alkalis, salts, and literally thouands of chemical compounds. Its use as a closure for innumerable articles of commerce attests to the chemical resistance and durability of cork. No other untreated, naturally occuring plant product can be used in contact with so many different materials.

More than one hundred and forty years have passed since chemists first endeavored to learn the composition of cork. Scattered papers have appeared from time to time on the chemistry of cork, but the literature on this subject still is limited. Within the past few decades some excellent research has been carried out on the cork constituents, and today we know more about the composition of cork than at any other time within the past two thousand years.

Fatty acids are found in cork, and the quantity present may be as high as 35 per cent. Hohnel[9] in 1877 discovered the presence of acid compounds in cork. Zetsche[10] and his co-workers have carried out extensive research on cork acids. Table 1 lists the

fatty acids and has been compiled from Zetsche's publications.

TABLE 1

FATTY ACIDS FOUND IN CORK

Name	Empirical Formula	Percentage of Total Acid	Percentage of Cork	Melting Point (Degrees C)
Phellonic	$C_{22}H_{44}O_3$	50–72	12–27	96
Eicosandi-carboxylic	$C_{22}H_{42}O_4$	1	0.3	123.5–124.5
Phloionolic	$C_{18}H_{36}O_5$	1.7	0.5	104
Phloionic	$C_{18}H_{34}O_6$	..	..	124

Drake[11] has shown phellonic acid, the principal fatty acid of cork, to be 22-hydroxytetracosanoic acid, $C_{24}H_{48}O_3$. The role of fatty acids in cork is not definitely known. They cannot be removed by extracting cork with solvents and are obtained when cork is saponified. This treatment causes the cork cells to separate, and therefore it is possible that the fatty acids function in binding the cells together.

Cork contains cerin, so called because it was first thought to be a wax, and friedelin, named in honor of the celebrated French chemist Friedel. Drake[12] and his co-workers have determined that cerin conforms to the empirical formula $C_{30}H_{50}O_2$, whereas friedelin has the composition represented by $C_{30}H_{50}O$. They are polycyclic compounds and belong to the polyterpene group.

The dark reddish-brown powdery substance that has been found in certain grades of cork is composed of compounds called phlobaphenes. They are complex substances, and very little is known about their chemical behavior. Phlobaphenes occur in nature along with tannins and according to Haas and Hill[13] are anhydrides of tannins.

Lignin constitutes from 25 to 32 per cent of cork. It can be removed by cooking granulated cork with sodium sulfite or any of the common lignin reagents. As with the fatty acids, lignin possibly functions in binding the cork cells together, for when it is removed the cork structure is broken down and the cells are separated. After the tannins, fatty acids, cerin, friedelin, and lignin have been removed from cork, the walls of the cork cells remain. The cell walls are very resistant to chemical action and are composed of cellulose and substances that closely resemble cellulose. They constitute about 25 per cent of the weight of cork.

Quantitative analysis of cork will vary with the quality and source of the sample. Cork specimens of different grades, of varying ages, and grown under different soil and climatic conditions will naturally give slightly different analytical results. However, a sample of good cork should be of the composition shown in Table 2.

TABLE 2

COMPOSITION OF CORK

	PERCENTAGE
Ash	0.1– 0.2
Moisture	3.0– 7.0
Tannins and phlobaphenes	2.5– 6.0
Fatty acids	28.0–35.0
Cerin and friedelin	2.0– 3.0
Lignin	25.0–32.0
Cellulose and celluloselike materials	25.0–32.0

Natural Cork

One of the oldest articles made from cork and one of the most widely known is the bottle stopper. For centuries cork has been used as a stopper for jars, vases, and jugs. The more general use of the glass bottle increased the demand for cork stoppers, and their manufacture grew into an important part of the cork industry. At first cork stoppers were made entirely by hand. Selected pieces of cork were cut into squares and then trimmed to shape and size. As the number of corks needed annually increased, special machinery was introduced to produce them. Today high-speed machinery is employed to punch, trim, bleach, and sterilize the millions of cork stoppers manufactured every year.

Cork stoppers are made in a wide range of sizes, from small corks for vials to bungs for barrels. Champagne corks must be of the very finest quality, but corks for general use may be of several grades. Usually corks are punched perpendicular to the annual rings, and therefore, the thickness of the cork slab determines the diameter of the stopper. A large percentage of the cork stoppers are tapered, but others, particularly those for the wine industry, have straight sides. A limited number of extra large corks is made by bonding together several pieces of cork. A small quantity of jar stoppers is made by cutting through the cork from the outside of the slab toward the inside. Wood or plastic tops are attached on some corks for decorative purposes.

The first sealing liners for crown caps were of natural cork, and a limited quantity of liners of this type are still produced. Slabs of cork are softened by steam and sheeted to the desired thickness. The liners are then punched and processed. A special process fills any pores in the liners with cork and renders them wholly impervious.

Another interesting and indispensable use of natural cork is in the manufacture of life preservers. There are two types, those strapped about the body, and the circular, or "doughnut," type known as ring buoys. Faubel[14] describes the construction of life preservers and discusses Federal specifications. In the manufacture of ring buoys dry pieces of cork are trimmed to fit into a ring-shaped mold. An adhesive material is spread between the pieces of cork, and wooden pegs are used to hold them together. The top is placed on the mold, compressing the cork as it is forced down, and made fast with clamps. The mold is then transferred to an oven and baked to set the adhesive. Afterwards, the mold is cooled and the cork ring is removed. Specially cut canvas is sewed around the buoy, and rope is attached. Ring buoys must comply with government specifications as to size, weight, and other details.

Life preservers are made of thick cork cut to fit a canvas jacket. The canvas covers are made first, and cork is placed in the pockets, which are then sewed together. The cork must be dry and of good quality. Inferior grades of cork are sometimes too heavy, or they may be very porous and too light. The cork in each compartment may be of one piece, or of several pieces skewered together, and is carefully trimmed and shaped to fit the canvas pockets.

An adult life preserver must contain a minimum of 5.5 pounds of cork and have a weight buoyancy of 20 pounds. When submerged in water the average person's weight is reduced to approximately one tenth of his weight in air. Accordingly, a 200-pound man could be kept afloat by an adult life preserver. Smaller sizes of life preservers for children have about 3 pounds of cork and a weight buoyancy of 10 pounds.

There are many uses of natural cork which are more or less familiar to everyone. Cork is used in the production of sporting goods. Fishing rod handles and bobbers for fishing lines are made of cork. Hunters use duck decoys of cork, and beach sandals are made with soles of natural cork. Whistles contain small cork balls. A recent patent concerns the use of cork in bowling pins.

A boatload of cork arrives at a United States port. Because cork is light, the bales are stacked on the ship's deck.

This life jacket is filled with light, buoyant cork which has passed Federal inspection. Photo courtesy Cork Institute of America.

Fishermen employ cork floats for their seines and nets, and large mooring buoys are made of cork. Cork floats are used for gasoline gauges. Handles of tools and penholder tips are made of natural cork. Cork is cut into sheets as thin as tissue paper and is used in the manufacture of cork tip cigarettes. Insoles for shoes are made of cork, and cork is used to build up shoes for the lame. Cork rings provide secure seals for wooden spigots in kegs.

There are many other applications of natural cork, but these are some of the important ones and will serve to show the extensive use of this interesting natural product.

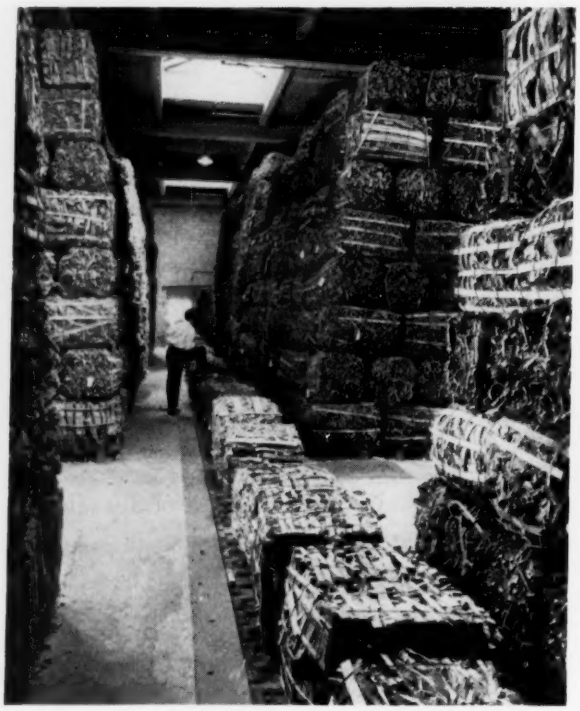
Composition Cork

Composition cork is prepared by coating clean, soft granules of cork with a suitable adhesive and curing the adhesive after the coated cork has been placed in molds. The adhesive is applied in such a manner that each cork particle is coated with only

a very thin film. Composition cork, therefore, consists mainly of natural cork and differs from natural cork only in that it contains a small quantity of artificial binding material.

The need for composition cork became apparent more than fifty years ago. The expanding use of stoppers and crown liners placed a great demand upon top grades of natural cork. At the same time a large quantity of high-quality scrap was accumulated for which there was no principal use. The problem of disposing of this waste, which consisted of trimmings from cork stoppers, crown liner scrap, thin bark of superior grade, and broken pieces of cork, became urgent. Some of this scrap cork was ground and used for packing purposes. Each granule was of excellent quality, and efforts were directed toward bonding the ground cork with a suitable adhesive and making a compounded, or composition, cork.

The task of making such a product was not an easy one, and the early types of composition cork exhibited various imperfections. In 1909, however, Charles E. McManus developed a satisfactory composition cork for the closure industry. Following this development, the use of composition cork rapidly expanded. In addition to extensive use in the beverage field, composition cork became an important material for manufacturing gaskets of many kinds, shoe inner soles, polishing wheels, friction rolls, cap liners for toilet preparations, and numerous other articles.



These bales of top-grade cork will soon be ground up to be manufactured into liners for crown caps.

Composition cork may be prepared in almost any form. It is molded in rods, flat blocks, round blocks, and special shapes. Among the adhesives generally employed are synthetic resins and animal and vegetable glues. The adhesives must be odorless, tasteless, and nontoxic when the composition cork is to be used to seal beverage or food product containers.

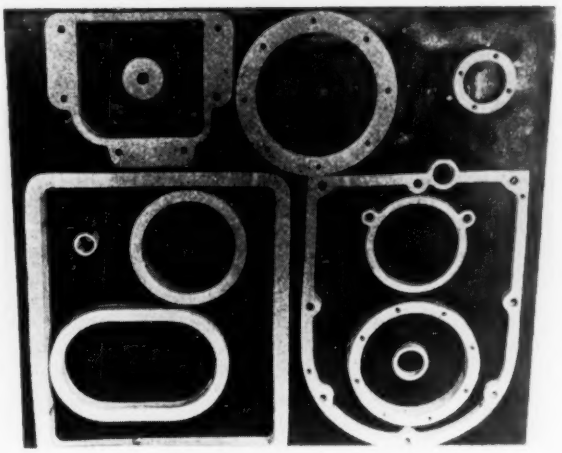
Cork is granulated in special mills which yield pure, clean, resilient granules. The granulated cork is transferred to mixing machines, and the proper amount of binder is added. A predetermined quantity of the binder-coated cork is placed in the mold, which is then heated. The exact temperature and duration of the heating period depend on the nature of the adhesive binder, the size of the mold, and other factors.

Composition cork rods are sliced into wafers, or disks, which are used as sealing liners for crown caps. For larger caps the liners are stamped or cut from composition cork sheets. The blocks of composition cork are cut into sheets, from which hundreds of articles are made. Composition cork blocks may be of any practical size, but the weight of the heavy molds and the necessary baking time generally determine the dimensions. Composition cork blocks may be made as large as $5' \times 2' \times 2''$. The sheets are cut into various thicknesses, depending upon the ultimate use. The round blocks are sliced into continuous sheets and ribbons by a special process.

In manufacturing composition cork the unique physical characteristics of natural cork are retained, and the chemical properties of the finished product correspond closely to those of the natural material. The artificial adhesives employed are soft, resilient, and durable. Composition cork is strong and flexible, and it is not affected by any chemical that does not weaken natural cork.

By varying the density of the blocks, composition cork for many purposes can be prepared. Variations in density are effected by altering the type and quantity of adhesive employed, varying the particle size of the granulated cork, or by employing different amounts of binder-coated cork. Through such changes in formulation and manufacture composition cork can be produced to meet a wide range of industrial requirements. Thus, composition cork is available in properties and dimensions for many industrial applications that natural cork cannot serve.

Composition cork might well be called the com-



Composition cork gaskets make efficient seals and may be cut into any desired form.

plement of natural cork. Although the manufactured product has in some instances replaced the natural article, at the same time composition cork has supplemented the use of natural cork and greatly broadened the field which cork serves.

Corkboard

The manufacture of corkboard insulation consumes a high percentage of our imports of unmanufactured cork. Natural cork because of its air-filled cellular structure is very resistant to the passage of heat. The heating of cork to produce corkboard causes cork to expand and increases this inherent thermal-insulating property. Corkboard insulation was invented in 1892 by John Smith, of New York. Some pieces of cork were heated unintentionally in a metallic container and, when cool, were found to be a strong unit mass. Heat had caused some of the resins present in cork to come to the surface of the particles, which were bonded together. Also, the expansion of the cork under heat forced the particles to spread into the voids between them and interlock, thereby forming a strongly united mass.

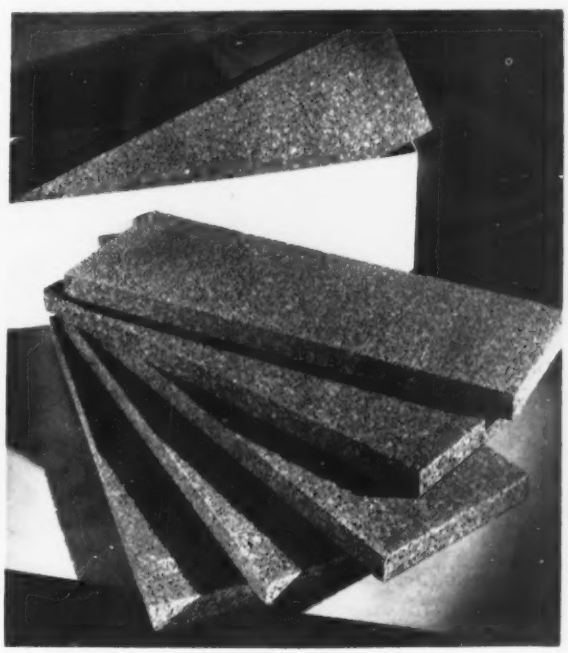
Since the invention by John Smith many improvements have been made in the manufacture of corkboard insulation. Several processes are employed today, and each is based on the discovery made by Smith over fifty years ago that cork expands when heated and some of the resins are brought to the surface.

In the manufacture of corkboard insulation, cork is granulated into coarse particles, which are transferred to molds that are covered securely. In one process superheated steam at approximately 600°F. is passed through the cork. Another method is by oven-baking, which is slower and requires 4–6 hours at temperatures ranging from 500° to 600°F. Blocks of corkboard vary in dimensions and they are cut into slabs and trimmed. A usual size is $12'' \times 36'' \times 1''$, but pieces 1.5 and 2 inches thick are also standard sizes. Larger slabs can be obtained if desired. The baking operation removes from cork some of the more volatile constituents which, together with expansion, yields a product of low density. Trimmed corkboard insulation weighs from 6.5 to 9 pounds per cubic foot.

Corkboard is employed also for machinery isolation and acoustical purposes. For machinery isolation heavier corkboard is required than for thermal insulation. The density varies up to 24 pounds per cubic foot, and loads as high as 8,000 pounds per square foot are carried. The corkboard absorbs jolts, reduces vibration and noise, and thus prolongs the life of the mounted machine. Low-density corkboard weighing about 5.5 pounds per cubic foot is employed for acoustical purposes. The porous surface, characteristic of corkboard, is excellent for absorbing sound waves and reducing noise.

Linoleum

Linoleum was developed in England about 1863. Originally linoleum consisted of oxidized and polymerized linseed oil, cork, and a backing of burlap or canvas. Cork is intimately mixed with the tough, rubberlike oil product, and the mixture rolled onto burlap sheets. The burlap backing gives strength



Corkboard is an efficient low-temperature insulation material.

to the linoleum, and the oxidized oil binds the cork particles together, which provide softness and resiliency.

The manufacture of linoleum was begun in the United States in 1873 and now constitutes a large and very important industry. The attractive patterns available today are the result of many developments and improvements during the past eighty-seven years, but the composition of linoleum has remained essentially the same. Pigments and resins are employed now along with cork, linseed oil, and burlap.

The cork used is of the best grade and is ground to a fine powder. In this condition the cork can be intimately dispersed throughout the oxidized oil and resins, giving a resilient product that can be calendered to a smooth surface. In some light-colored linoleums, wood flour is substituted for the tan-colored cork flour. Pigments are added to give the desired shade. Plain linoleum and a large variety of printed patterns and inlaid designs are manufactured.

Cork Tile

Cork tile is manufactured by baking cork shavings and particles under high pressure. The interlocking of the expanded cork particles, together with the resins from the cork, holds the many pieces in a strongly bonded single mass. The cork is packed by hydraulic presses into strong molds and baked 7–10 hours at 450°–600° F. By varying the time and temperature different shades of cork tile can be produced. Dark and light shades are employed in floors to give attractive patterns. Cork tile makes quiet, warm, durable, and resilient floors.

Production and Trade Data

During the past half century the production of cork products in the United States has steadily increased. For normal manufacturing requirements approximately 160,000 tons of unmanufactured cork are imported annually by this country. Table 3 shows the rise in cork imports during the past 50 years.

Production of cork products in the United States is closely related to imports of unmanufactured corkwood. In the past 50 years the value of cork products produced in the United States has increased almost ninefold. Table 4 shows the rise of cork manufacturing in this country from 1899 to 1947.

The greater portion of cork products originating in this country is consumed at home. However, our exports of manufactured cork items now total a substantial amount and in 1947 were more than $1,500,000.

TABLE 3

IMPORTS OF UNMANUFACTURED CORK, UNITED STATES*

Year	Tons (Metric)	Value
1899	.....	$1,147,802
1909	35,530	2,016,534
1921	50,078	2,357,159
1927	101,192	5,375,283
1929	121,380	8,228,483
1933	84,905	2,854,945
1936	98,153	4,580,071
1939	103,226	4,090,466
1945	119,078	8,907,926
1947	140,797	14,659,599

* Bureau of Foreign and Domestic Commerce, U. S. Department of Commerce.

Although the United States is the largest consumer of cork, the use of cork during the past half century has increased also in other countries. The rising demand for cork products here and abroad has had its effect on the cork-producing countries of the world. Because of the commercial value of the commodity, steps have been taken to preserve cork forests and to market the harvest efficiently. Forest areas have been given better care, and in many cases the previously neglected forests have been taken over by the national governments. This attention has resulted in a substantial increase in the production of corkwood in practically all the cork-producing countries in the past fifty years. Ryan[15] gives the forest area and production for each of the cork-producing countries and discusses growth factors of the cork tree.

Portugal is the world's largest producer of cork, supplying almost 50 per cent of the total corkwood produced. The total area of Portugal's cork forests amounts to approximately 1,720,000 acres. The annual yield is about 140,000 metric tons, and approximately 80 per cent is exported in the unmanufactured state. Within the past thirty years production in Portugal has notably increased.

Spain stands second in importance in corkwood production. The total area of the cork forests in

TABLE 4

CORK PRODUCTION IN THE UNITED STATES*

Year	Value	Year	Value
1899	$4,392,000	1933	$11,604,000
1909	5,940,000	1935	13,987,000
1921	12,967,768	1937	21,783,000
1927	17,369,000	1939	17,724,000
1929	23,656,117	1947	35,100,000

* Census of Manufactures, U. S. Department of Commerce.

Spain is approximately 622,000 acres, from which 70,000 metric tons of corkwood were obtained in 1941. About 40 per cent of the corkwood produced in Spain is consumed at local factories, and a high percentage of Spanish cork exports consists of cork products.

The cork area in Algeria is quite large, the total being about 1,100,000 acres. Approximately one half this area is under government control. The estimated production of private and government forests amounts to about 35,000 metric tons each year. Most of the Algerian cork is exported in the unmanufactured state, but a small percentage of the yield is consumed locally in the manufacture of corkboard insulation.

France has a cork forest area of about 350,000 acres, and the yearly production is estimated at 10,000 metric tons. This small yield does not supply the local demand, and France imports both unmanufactured corkwood and cork products.

In Italy the greater portion of the cork area, which totals about 247,000 acres, is divided between Sardinia, which has 190,000 acres, and Sicily, where the acreage is about 40,000. The yearly production ranges from 8 to 9 thousand metric tons. Much of the Italian cork, about 35 per cent, is consumed locally in the manufacture of various cork products.

The cork forests in Tunisia cover about 235,000 acres, and some 7,000 metric tons are produced annually, of which approximately the entire amount is exported in the unmanufactured state.

French Morocco contains a large cork forest area, which totals about 741,000 acres. Production is estimated at 16,000 metric tons annually. There are no cork factories in French Morocco, and practically all the export trade consists of unmanufactured cork. There are approximately 74,000 acres in Spanish Morocco. The potential annual yield is estimated at 6,000 metric tons, although there has been little or no production in recent years.

Within the past half century efforts have been made to grow the cork oak outside its native habitat. Success has been achieved in establishing a substantial number of cork trees in some countries, particularly in the United States, but only time will tell whether these new cork regions will result in the development of commercial plantings.

Through the centuries cork has continually served mankind and is today an essential material in our modern civilization. Because of the unique properties of cork, the production of cork and cork products has grown into a large and important world-wide industry. After more than 2,300 years of uninterrupted use, cork continues to be a necessary commodity.

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Galileo and the Telescope

EDWARD ROSEN

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Galileo did not invent the telescope. His predecessors used it mainly to look at distant objects on land or sea, military advantage being their dominant thought. In their hands the new device might properly have been called a spyglass or field glass. Yet some of them conceived of testing its power by turning it toward the sky. Thus a report published in 1608 said of the glasses made in Holland: "They serve well in sieges and on similar occasions, for at a distance of a league or more everything can be examined as clearly as if it were quite close to us; and even the stars which ordinarily do not appear to our sight and to our eyes, on account of their small size and the weakness of our vision, can be seen by means of this instrument." Months before its existence became known to Galileo, these intimations of its value for astronomy were circulating in print. They show that, just as he did not invent the telescope, so also he was not the first to look at the heavens with it. They also show how lesser men stopped just short of significant discoveries.

The optical innovation, then, had been handled by many people in several countries for an extended period before Galileo first heard about it in the year 1609. The month and day cannot be fixed, because his chronological references to the event are not very definite, and seem slightly discrepant. But in any case it was probably the early summer of that year when the floating seed alighted on the rich soil it needed. Galileo, then professor of mathematics at the University of Padua, chanced to be in Venice, some twenty-five miles away. While he was in the city of lagoons, as he later told the story,

> The news arrived that a Dutchman had presented Count Maurice with an eyeglass which showed distant objects as perfectly as if they were quite close. Nothing further was added. At this report I went back to Padua, where I was then living, and set about thinking this problem over. The first night after my return I solved it. The following day I made the instrument, and gave an account of it at Venice to the same friends with whom I had discussed this matter the day before. Then I applied myself at once to making a better one, which I took to Venice six days later. It was seen there with great astonishment by almost all the leading gentlemen of that republic for more than an entire month, but I was very weary. Finally, on the advice of one of my sympathetic supporters, I presented it to the Doge before the full Collegio. The esteem and admiration with which he received it are testified by the Doge's letter, which is still in my possession. In it that most serene prince munificently renews my appointment as a reward for the invention presented to him, and confirms me for life in my professorship at the University of Padua, with a salary twice that which I had before and more than three times that of any of my predecessors.

So Galileo narrated the episode over a decade later in *Il Saggiatore,* which he published in 1623. The relevant order from the Doge to the local authorities at Padua still survives in the original. It is dated August 25, 1609, as is likewise the Senate's resolution, which it transmits. These two official documents thus provide a secure starting point for reconstructing the story of how one man changed a minor implement of warfare into a major tool of scientific investigation.

To accompany the telescope presented to the government that employed him, Galileo composed a letter in which he declared that the device had a magnifying power of nine diameters. He also indirectly answered a question that must have been put to him hundreds of times in the previous month: "How is it made?" He had undoubtedly resorted to evasion, for he confidently expected to increase his income and enhance his prestige if he could retain exclusive possession of a technical secret. In his letter of presentation to the Doge, he

explained in a spirit of deliberate mystification that he had "dug the instrument out of the most abstruse speculations of the science of perspective." Half a year later, all that he was willing to say in his *Sidereal Message* was that he had "relied on the doctrine of refractions."

But after the mathematical theory of the instrument had been elaborated and had become public property, in *Il Saggiatore* he went into detail:

> We are certain that the Dutchman, the first inventor of the telescope, was a simple master of ordinary eyeglasses who accidentally, while manipulating lenses of several kinds, happened to look at the same time through two of them, one convex and the other concave, placed at different distances from the eye. In this way he saw and observed the resulting effect, and invented the instrument. But I, stirred by this news, found the same thing by the path of reason. And since the reasoning was quite easy, I should like to exhibit it.

At this point we are privileged to witness a mental operation of rare simplicity and clarity. Galileo continues:

> This device consists of either a single lens or more than one. It can't be only one. For the shape is either convex, that is, thicker in the middle than toward the rims; or concave, that is, thinner in the middle; or the surfaces are parallel. But this last shape does not alter visible objects at all by enlarging or diminishing them. The concave does diminish them, and the convex enlarge them, but they appear very indistinct and blurred. Therefore a single lens is not enough to produce the effect. Passing then to two, and knowing that the lens with parallel surfaces alters nothing, as has been said, I concluded that neither could the effect follow from coupling this with one of the other two. Hence I confined my efforts to testing the result of combining the other two, that is the convex and the concave, and I saw that this gave me what I was after. Such was the progress of my discovery.

Observe that Galileo called the Dutchman, whose name he did not know, "the first inventor of the telescope" (*primo inventor del telescopio*). Nowadays such a designation would sound like a pleonasm, like an unnecessary repetition. We are inclined to restrict the title "inventor," for each gadget or concept, to the individual with an unmistakable chronological priority. Galileo's expression may recall to our minds the radio announcer's reference to his "listening audience." But in seventeenth-century English, as in seventeenth-century Italian, "first inventor" still occurred quite commonly.

In this connection the title-page of the *Sidereal Message* is instructive. Galileo there claimed that "he was the first to discover Jupiter's satellites, known previously to nobody." In sharp contrast to this unqualified pronouncement, he mentioned the telescope "recently found by him." In the body of the book, moreover, he related how the news of the instrument's existence stimulated him to thinking along these lines. He did not pretend to be its inventor, in the modern sense. But he did invent (that is, find a way of making) a telescope.

The excitement engendered at Venice by this product of his theoretical insight and mechanical ingenuity is reflected in a chronicle kept by a leading political figure of the republic, who at the time was one of the three administrators of the University of Padua. The chronicle records that on August 21, 1609, Galileo, accompanied by the author and a group of distinguished citizens, climbed a steeple "to see the marvels and the singular effects of the said Galileo's tube. . . . Placing it at one eye while the other was closed, each one of us saw distinctly . . . the steeple, dome and facade of the church of St. Justina in Padua . . . and many other truly wonderful details in the lagoon and in the city. . . . Then it was presented by him in the Collegio on the 24th of the month."

Galileo wrote to his brother-in-law in Tuscany:

> Six days ago I was called by the most serene Signory. I had to show my instrument to them, and at the same

GALILEO GALILEI: 1564–1642

(Reproduced from "Portraits of Eminent Mathematicians," by David Eugene Smith. New York: Scripta Mathematica, 1936 and 1938).

time to the entire Senate, to the unbounded amazement of all. Numerous gentlemen and senators, despite their age, have more than once climbed the stairs of the highest steeples in Venice to discover at sea sails and ships so far away that though they proceeded under full sail toward the port, two hours or more passed before they could be seen without my telescope. For, to sum up, the effect of this instrument is to represent an object, say, fifty miles away as big and close as if it were five miles away.

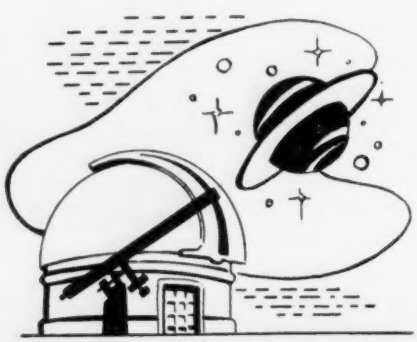
After telling about his decision to present the telescope to the Doge, Galileo went on to report a conversation with the author of the above-mentioned chronicle:

The most illustrious and most excellent procurator Priuli, who is one of the administrators of the University, came out of the Collegio. Taking me by the hand, he told me that the most excellent Collegio, knowing the manner in which I had served for seventeen years in Padua, and also recognizing my kindness in presenting them with something so agreeable, had immediately ordered the university administrators, if I were satisfied, to renew my appointment for life, with a stipend of 1000 florins a year; since I still lacked a year to complete the previous appointment, they wanted the stipend to begin accruing to me from that day, making me a gift of the increment for a year, that is, of 480 florins, worth 6 lire, 4 soldi, a florin. Knowing that hope's wings are very sluggish and fortune's very swift, I said that I was satisfied with what His Serenity decided. Then the most illustrious Priuli, embracing me, said: "I am in charge this week, and it is my turn to command as I please. It is my wish that today, after dinner, there shall be a meeting of the Pregadi, that is, the Senate, and that your reappointment shall be read there and voted on." So it was, being adopted in full force by unanimous vote. Thus I find myself bound here for life, and I shall have to be satisfied with enjoying my native land at intervals in the vacation months.

This letter is stigmatized as of doubtful authenticity, in the magnificent national edition of Galileo's collected works in twenty folio volumes, issued by the Italian government in the name of the people to honor one of their greatest sons. It is no light matter to differ on such a question with the editor, whose vast erudition and intimate knowledge of Galileo's life and writings have never been surpassed. Yet I am persuaded that the letter is genuine, though the necessary argumentation, unavoidably long and detailed, will be omitted here.

If the letter is authentic, Galileo told his brother-in-law that the instrument presented to the Venetian government in 1609 magnified ten times (he put it at nine times, in the letter accompanying the presentation). By the beginning of the next year he succeeded in raising the magnifying power to twenty. With this increase he found the mountains on the moon and the satellites of Jupiter. In the *Sidereal Message* he described a handy method of determining whether a telescope had this power: "Cut out two paper circles . . . one of which is four hundred times larger than the other. This will be the case when the diameter of the larger one is twenty times the length of the diameter of the other one. Then, attaching both surfaces to the same wall, look at them simultaneously from a distance, at the smaller one with one eye applied to the telescope, at the larger one with the other free eye. This may be conveniently done at one and the same time with both eyes open. Both figures will appear of the same size if the apparatus magnifies objects in the desired proportion." But he had already pushed ahead to a power of thirty, and in August 1610 he informed Kepler that his best instrument was about thirty-two. This strength was necessary, he told the leading Jesuit astronomer in Rome, to verify his discovery of Saturn's strange shape.

He could advance no further in the direction he had chosen, with a concave eyepiece that permitted the rays of light to diverge. The available materials and methods of production yielded only one satisfactory instrument out of every ten made in his workshop. Yet, despite these handicaps, with the limited tool which he devised and built himself, he brought the long era of naked-eye observation to an end, and within a relatively brief period he made a series of discoveries perhaps unequaled in the history of astronomy or even in the history of science.



SCIENCE ON THE MARCH

THE NATIVES OF SOUTHERN AFRICA: THEIR "MEDICINE" IN MODERN THERAPY

SINCE the publication of a brief review of several plants used by native tribes, or Bantu, in Southern Africa[1] it has been found possible to accumulate from several sources further interesting details of other herbal remedies and plants used by these peoples. Basically, the object of these studies was to draw attention to drugs used by the natives for many types of illness, drugs which may also repay further study as potentially useful additions to the growing range of medicaments in the hands of the medical profession. So many were the fascinating side issues that appeared during the work, however, that it became impossible to eliminate them and concentrate entirely on the bare bones of botanical and therapeutical description. Native psychology and still-primitive beliefs color the picture at every stage, and it is necessary to realize that the natives of South Africa are not of one but of many races—Pondos, Zulus, Swazis, Basutos, Bechuana, Bapedi, Xosas (originally "Kaffir"), Hereros, Matabele, Bavenda, and others. This variety complicates research, but even more puzzling is the almost general belief, common to all the native races in varying degree, in the witch doctor or the "doctor of bones." The latter pretends to forecast events or actions by the manner in which his *Indawuli* (bones) fall when cast to the ground, whereas the witch doctor makes use of very many naturally occurring herbs, roots, barks, etc. (his *muti*), the secrets of which are passed down from generation to generation.

It may seem strange that in a city like Johannesburg such sorcery and witchcraft can exist side by side with modern amenities, but such is the case, and the elimination of the ancient beliefs is a slow and tedious process.

Fifty years ago a native houseboy from the Cape, Bernard Mizeki, who became a Christian, was murdered near Salisbury, Southern Rhodesia, and there seems little reason to doubt that he was killed because he had undermined the influence of the witch doctors. Today the belief in witch doctors, although probably on the wane, is still strong, and only recently the Johannesburg *Sunday Times* reported the presence as a spectator in a Port Elizabeth police court of a native woman witch doctor, Lilian Pama, complete with leopard-skin cap as a badge of office and flicking an oxhide whip to chase away "evil spirits." Apparently she "can fix stomach-ache good" and treat stab wounds, childbirth complications, and numerous other troubles.

Thus the past still colors the present; nevertheless the following notes on plants and herbs of Southern Africa may stimulate a study by accepted scientific methods of their potentially useful properties. As a means of classification it is probably as well, in view of the wide range, to use the accepted botanical families, as this will also give a rough general indication of the type of plant under discussion.

Amaryllidaceae: In this lily family a plant of interest is *Buphane Disticha* (*Toxicaria*) Herb. or *Haemanthus toxicarius* Thumb. or *Amaryllis disticha* L. (Cape poison bulb, *gifbol*; Xosa, *iSwadi*; Suto, *lešôma, kxutsana-ya-na-ha*). It is poisonous (particularly the bulb) but is used by the natives as an outer dressing after circumcision (Xosa) and is said to "draw" pus. Apparently the Hottentots have used the bulb for poisoning arrows intended for killing small game. Various workers (Juritz, Tutin, and Lewin) have isolated amorphous alkaloids from the bulb. Tutin obtained buphanine having an action similar to hyoscine (scopolamine), and this on hydrolysis gives a crystalline alkaloid buphanitine. At the same time he isolated three minor alkaloids and a water-soluble alkaloid similar to colchicine in action. Lewin at about the same period (1911) obtained an amorphous alkaloid, haemanthine, with an action similar to buphanine. This is narcotic with a weak cardiac effect, and subcutaneously it produces emesis as well as narcosis.

Moraceae: This is the family embracing several varieties of fig. The most interesting member is *Cannabis sativa* L. (*Cannabis indica,* Indian hemp, hashish, ganja, dagga; Xosa, *um Ya*; Suto, *matakwane, mmoana*), which has been known in medicine for many years as a habit-forming drug. It has been used by the natives as a snake-bite remedy, for malaria, dysentery, and anthrax, and Suto women smoke the drug to ward off pains of childbirth. The inclusion of cannabis here is due, however, to the social problem posed by its use by

the South African natives. They smoke it as an intoxicant under the name of dagga, and in the Orient it is similarly used (hashish or bhang). In Brazil, Mexico, and the United States cannabis is the active ingredient of marihuana cigarettes.

Cannibas sativa is actually indigenous to central Asia, and in the North and West Himalayas, but it is cultivated (generally illegally) in tropical areas of Africa, India, and North America. It contains a brown resin, cannabinone, the chief constituent of which is a red oil containing cannabinol ($C_{21}H_{26}O_2$). The drug is a powerful narcotic and produces a type of inebriation, mental confusion, and hallucinations, followed by decreased sensitiveness to touch, pain, and muscular relaxation. Comatose sleep ensues.

In South Africa the problem of dagga and its illegal use has assumed such serious proportions that the government has appointed a Dagga Commission to inquire into the whole question. Subterfuges used by growers of the herb are many—planting between rows of cereal products such as mealies and sowing in back yards and on isolated patches of veld are but a few methods—and the number of ruses to avoid detection by the police in vending and trafficking brings to mind episodes in the career of Russel Pasha!

The illegal production and use of dagga in South Africa are, however, most serious problems and bear, in many cases, a close relationship to the drinking dens, or shebeens, which often serve as distribution points for the drug to addicts. The misery that dagga causes cannot be assessed, but there is no doubt that its use precedes much of the violent crime that the police of Johannesburg and other large centers are battling to suppress.

Red dagga, or Wilde dagga, is a different plant altogether and is a member of the family Labiateae. This is *Leonotis Leonurus* R. Br. (Zulu, *u-Munyane*; Suto, *lebake*), and it has been recorded that the Hottentots smoke it instead of tobacco. A decoction of the leaf has also been used as a strong purgative and emmenagogue. It is feebly narcotic but probably harmless when smoked. The plant is also mildly anthelmintic. From the leaf Copeman in 1923 isolated a reddish oil and two phenolic compounds.

Polygonaceae: Many species of dock have been used medicinally for various purposes, and the yellow dock, sour dock, and Tongblaar (Xosa and Zulu, *iDololenkonyana*) are of interest. Botanically this plant is probably *Rumex Crispus* L., the root of which contains oxymethylanthraquinone, and the dried root emodin and chrysophanic acid. It is mildly purgative and astringent. This, with other species of *Rumex,* has been used by the natives for the treatment of tapeworms and roundworms.

Aizoaceae: A species of *Mesembrianthemum, M. Tortuosum* L. (Kon, Channa), is reported to be powerfully narcotic, and the Hottentots chew the leaves for toothache and abdominal pains. In the Queenstown, Cape Province, area this plant is used as a narcotic by the natives. Many years ago several workers investigated the constituents of this plant, and an amorphous alkaloid, mesembrine $C_{16}H_{19}O_4N$, has been isolated. The action of this substance is reported to resemble that of cocaine, but it has a weaker local anesthetic effect. Little work has been reported since 1914, and a further review of the constituents of this plant might be well repaid.[2]

Crassulaceae: *Cotyledon Orbiculata* L. (*Hondeoor,* pig's ear, Varkenoore; Xosa, *iPhewula*; Suto, *seredile;* Zulu, *inTelezi*) is reported to be widely used in South Africa. The plant has thick, succulent leaves and bears clusters of pink, pendulous, bell-like flowers. The juice expressed from the fresh leaves has been used for epilepsy, and, quite diversely, the succulent part of the leaf is used to soften hard corns by Xosas and Europeans in South Africa. Again, the Xosas use the warmed leaf juice as drops for earache and toothache, and the Zulus use a decoction as an enema in syphilis. In spite of this variety of uses, the plant is poisonous, and in animals symptoms of narcotic poisoning have been noted after the plant has been ingested.

In 1926 Kamerman isolated from the fresh leaves a bitter, colorless compound he called cotyledontoxin, which principle depresses sensation when applied locally, and apparently depresses the central nervous system. Cotyledontoxin is reported to belong to the picrotoxin group and does not occur in the leaf juice. Picrotoxin itself resembles strychnine in action and finds application in chorea and cases of poisoning by the barbiturates.

The toxicity of this plant varies with the type of soil; apparently a clay soil is conducive to a higher toxicity. Further, sun-drying of the leaves does not affect toxicity.[3]

Compositae: Of this widely dispersed family, *Dicoma anomala* Sond. (Maagbossie, Gryshout, Wormbos; Suto, *hlwenya*; Zulu, *uMuna;* Xosa, *inMyongwane*) is worthy of mention. The root of this plant is used for dysentery and diarrhoea, and the Sutos are reported to make a decoction for

the treatment of venereal diseases and as a purgative. A similar preparation is used by the Zulus for a vague group of "blood disorders," and the Bantu in general use the plant for coughs and colds. The powdered root bark apparently causes coughing and sneezing. The plant has been investigated by Tutin and Naunton,[4] who found a small percentage of volatile oil, a colorless glycoside, an amorphous alkaloid, and a phytosterol-like substance, but no work appears to have been done on the true action of the latter three constituents.

Books could be, and indeed have been, written on the subject of native medicine and lore.[5]

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STATISTICAL CONTROL IN HYDROLOGIC FORECASTING*

With growing demands for water, especially in the semiarid West, there has come a corresponding increase in the need for predicting the flow of streams. As a result, stream-flow forecasting has become big business, with a large number of individuals and organizations taking active part, and efforts are continuously being made to improve the reliability of the forecasts.

There are two main aspects to the problem of obtaining more accurate forecasts: ascertaining factors that can be measured in advance of the runoff to be predicted and that are highly correlated with it, and working out a reliable method for expressing this correlation and predicting the expected yield or discharge rate. Much work has been done on the first of these aspects. Garstka,[1] for example, describes what has been done by the Bureau of Reclamation in improving water-yield forecasts for the Snake River watershed in Wyoming. In this work the water content of snow, measured at each of a series of snow courses, was weighted by the relative area of the watershed to which the course data applied. These values were used to obtain an adjusted average snow water content that could be correlated with the water yield for the period from April through July each year.

After the correlated factor or factors have been found and measured, however, the other aspect of the forecasting problem comes in. The forecaster has to work out an unbiased relation of water yields to the measured factor, and make forecasts through the use of this relation and new data on the correlated factor. Because the relation cannot be exact, it is also important to estimate the error of each forecast. This statistical aspect of forecasting has been receiving increased attention. Although a number of workers still employ the graphic techniques that are commonly used by hydrologists, others are applying the methods of regression and correlation analysis presented by Ezekiel[2] and others. When these are modified to fit the requirements imposed by relatively short-term records, they are well adapted to use in water-yield forecasting.

The Use of Regression in Forecasting

In this discussion Garstka's data from the Snake River watershed will be employed, with water yields for the period from April through July for a series of years, and "elevation-weighted" average water contents of snow on the snow courses, taken about April 1 of each year (Table 1). In Garstka's article this relation was analyzed by graphic means, and the scatter of the points was bounded by parallel lines expressing a "band of error," to show the probable limits within which a new yield was likely to fall. This method of analysis is widely used and gives satisfactory results where moderate precision is required. But in most cases mathematical control, using least-squares regression and associated statistics, is likely to give more reliable results.

In this kind of analysis the data should conform reasonably well to certain statistical assumptions. For one thing, it is assumed that they are a random sample of a larger population of data, and that the next year's runoff (as yet unmeasured)

* Condensed from a more detailed paper of the same title, by H. G. Wilm. Research Note No. 61, Pacific Northwest Forest and Range Experiment Station, Portland, Ore., January 1950.

TABLE 1

ANNUAL WATER YIELDS AND WATER CONTENT OF SNOW, SNAKE RIVER ABOVE JACKSON LAKE, WYOMING (1919–30)

(1) Year	(2) Water Content of Snow[a]	(3) Water Yield[b]
1919	23.1	10.5
1920	32.8	16.7
1921	31.8	18.2
1922	32.0	17.0
1923	30.4	16.3
1924	24.0	10.5
1925	39.5	23.1
1926	24.2	12.4
1927	52.5	24.9
1928	37.9	22.8
1929	30.5	14.1
1930	25.1	12.9
Total	383.8	199.4
Average	31.98	16.62
1931	12.4	

[a] Elevation-weighted average water content of snow on snow courses, about April 1 each year.

[b] Total yield of water from watershed above Jackson Lake, April through July each year.

can be considered as drawn independently from this same population. It is also assumed that the deviations of water yields (Y, dependent variable) around any single value of X (the independent variable) are random and normally distributed. Ordinarily both assumptions may be considered fairly safe in the analysis of water-yield data over relatively short periods.[3] If so, we can determine a "least-squares" relation between water yields and snow water content, and can set up a suitable technique for forecasting and for estimating the error of the results.

As a first step we must set up some logical hypothesis about the true shape of the regression line: whether it is straight, or what form of curve it should assume. We might argue, for example, that the regression of water yields on snow water content should be a curve that is concave upward. In the Snake River data, however, this shape is undetectable. Therefore we can make use of the simplest hypothesis, that the true regression is satisfactorily fitted by a straight line, a sample estimate of which is provided by a linear equation in the familiar form,

$$E = a + bX. \tag{1}$$

Associated with this sample regression equation are two kinds of error in its estimate of the true equation: the error of the "origin," a, and that of the regression coefficient, b. When, as in forecasting, we want to estimate the value of a single new water yield from the sample equation, there is an additional component of error associated with this single value. The combined magnitude of all three of these components may be estimated by the following equation:

$$s_E^2 = s_{y \cdot x}^2 (1 + 1/n + x^2/S_x^2), \tag{2}$$

where s_E is the standard error of the forecast; $s_{y \cdot x}$ is the standard error of estimate of the linear regression equation; n is the number of observations on which the regression was based; x is the deviation of a new year's snow water content from the average used for the regression; and S_x^2 is the summed squared deviations of the water contents used in the regression, from their average. For those who are not familiar with these methods, very clear and readable discussions are given by Snedecor.[4]

As in any statistical analysis employing small samples, the standard error of the predicted water yield ($\pm \sqrt{s_E^2}$) is multiplied by an appropriate value of Student's t [5] in order to provide an estimate of the "fiducial intervals" around the forecast E:

$$\text{Fiducial limits} = E \pm ts_E. \tag{3}$$

At any desired probability level, these fiducial limits can be expressed as a band of error around the sample regression line. The lines bounding this band are not parallel to the regression line; on the contrary, the fiducial limits of a forecast grow larger as the average snow water content deviates more and more from the mean. They may be very large if forecasts are made from values of the independent variable that are close to, or beyond the range of, available sample data.

The use of statistical control can be illustrated with an example, employing the figures on water yields and snow water contents in Table 1. From these data is computed a linear regression equation such as (1):

$$E = \bar{y} + b\,(X - \bar{x}) = a + bX^{\dagger}$$
$$= 16.62 + 0.5477\,(X - 31.98) = 0.5477X - 0.8954.$$

By inserting the average result of the 1931 snow surveys into this equation (12.4 inches, see bottom Table 1) we can obtain a forecast of the most probable water yield for this new year:

$$E = (0.5477)(12.4) - 0.8954 = 5.9 \text{ inches of water.}$$

It is still early in 1931 when this forecast is made, so of course we have no knowledge as to the actual water yield for this year; but we can estimate the probable range within which it should lie, on any desired odds. This procedure is begun by calculating the variance of the forecast, using Equation (2):

† Here, $\bar{y}$ and $\bar{x}$ are the arithmetic averages of the data in Table 1.

$$s_E^2 = s_{y \cdot x}^2 (1 + 1/n + x^2/S_x^2)$$
$$= 3.392\,[1.083 + (12.4 - 32.0)^2/768.46]$$
$$= 3.392\ (1.583) = 5.3695.$$

From the calculated variance we can obtain fiducial limits of the forecast (Equation 3) at any desired probability level. With 10 degrees of freedom, if we choose the 0.10 level the limits are:

$E \pm t_{.10} s_E = 5.9 \pm 1.81\ \sqrt{5.3695}$, or from 1.7 to 10.1 inches of water. You might also like to figure the limits at the 0.50 level; these would be:

$5.9 \pm (0.70)\,(2.32)$, or from 4.3 to 7.5 inches.

Then you will want to convey this information to the water user, perhaps using a statement like this:

For 1931, the odds are even that the April–July yield of water will be between 4.3 and 7.5 inches. This might, of course, be an unusual year. Unless it is the kind that comes only about once in a decade, however, you will get more than 1.7 and less than 10.1 inches of water.

Perhaps you can work out a phrasing that is better suited to your needs. But the important thing is to tell the water user the real limits between which his water yield is likely to be, rather than to give him an "exact" figure which, sooner or later, is sure to weaken his confidence in your predicting ability.

When the 1931 water yield has actually been measured (8.8 inches, in the top line of Table 2), we can see that it fell safely within the fiducial limits at the 0.10 level; it deviated only 2.9 inches from the forecast value. If you wish, you can calculate the probable frequency with which a deviation of this size is likely to occur, by calculating for this particular forecast:

$$t = (Y - E)/s_E = 2.9/2.32 = 1.25. \qquad (4)$$

By looking up t (on 10 D/F) we can see that this kind of deviation is likely to occur about once in four trials in the long run: the probability lies between 0.2 and 0.3.

To show how this method of forecasting worked out for each of a series of forecasts up to and including 1945, Table 2 gives the forecast value for each year, the difference between observed and forecast yields, the standard error of each forecast, and the value of t obtained by means of Equation (4). If we compare these t's with the tabular values for the associated degrees of freedom, we can see how the forecast deviations for these new years conformed to the theory. As shown by the asterisks, only 1 of the 15 forecasts fell outside the fiducial limits calculated at the 0.05 level, and 3 (or 20 per cent) outside the 0.20 limits.

Progressive Development of the Regressions

While examining the successive forecasts in Table 2, you may feel that we have done something a little risky in making forecasts so far beyond the period included by our regression. When you look at the "degrees-of-freedom" column, however, you will guess that up to 1939 each forecast was based on a new regression, containing all the available observations up to date. Within definite limitations, this procedure has decided advantages. For one thing, the regression equation is based upon a growing number of observations, and should therefore become more stable with increasing periods of record. For another, the forecaster has to move only one year beyond his equation in making the forecast for each new year.

With a longer and longer record, however, there comes an increasing risk that all the data in the period do not belong to the same population as the new year for which a forecast is made. This would be true, for example, if there is any long-term tendency toward cyclical fluctuation in water yields or precipitation. Then it may be better to drop off one or more of the earliest years of record as new years are added, keeping only enough data so that the errors of the equation itself will be kept within satisfactory limits.

Keeping Control over the Forecasts

In order to know when to start using "moving regressions" by dropping off early years, the forecaster can exert a form of control somewhat like

TABLE 2

ANNUAL WATER YIELDS AND WATER CONTENTS OF SNOW, SNAKE RIVER ABOVE JACKSON LAKE, WYOMING (1931–47)

(1) Year	(2) Water Content of Snow (inches)	(3) Observed Water Yield (inches)	(4) Forecast Water Yield (inches)	(5) Difference (3) – (4) (inches)	(6) Standard Error of Forecast (inches)	(7) Degrees of Freedom	Student's t[a]
1931	12.4	8.8	5.9	+2.9	2.3	10	1.26
1932	35.1	17.4	18.3	−0.9	2.0	11	.45
1933	31.5	14.9	16.4	−1.5	1.9	12	.79
1934	21.1	10.5	11.2	−0.7	2.4	13	.29
1935	27.6	16.1	14.4	+1.7	1.8	14	.95
1936	30.7	18.9	16.0	+2.9	1.8	15	1.61*
1937	23.2	13.6	12.4	+1.2	1.9	16	.63
1938	28.6	20.0	15.2	+4.8	1.8	17	2.67**
1939	28.2	14.8	15.2	−0.4	2.1	18	.19
1940	19.2	13.6	11.4	+2.2	2.3	13	.96
1941	17.0	12.2	10.8	+1.4	2.1	13	.67
1942	19.1	14.5	12.0	+2.5	2.2	13	1.13
1943	40.1	25.2	21.0	+4.2	2.5	13	1.68*
1944	17.7	13.0	11.4	+1.6	2.5	13	.64
1945	24.5	15.1	14.8	+0.3	2.4	13	.12

[a] Asterisks indicate the range of probabilities which include these values of t: No asterisk, probability greater than 0.2; * probability 0.2–0.05; ** probability less than 0.05.

the "quality control" methods employed in manufacturing, and can make the necessary adjustments as a part of this process. While doing so he can, incidentally, watch for and remove errors in the data that might become persistent. If, for example, a new observer takes his snow course data incorrectly, it may introduce a consistent error into his observations in some particular year; and the results are likely to show up in the relation between the forecast water yield and the snow water content. As each forecast is compared with the observed water yield, the forecaster will notice whether the deviation is larger than might be expected by chance. If so, he will look for possible causes and see that they are removed before the next season's data are collected. If deviations from prescribed techniques are observed, their correction cannot help the past year's forecast; but it may do a great deal to keep future forecasts as reliable as possible.

A more serious problem arises when a real and progressive change develops in the relation of water yield to snow water content. Such a shift can be detected when successive forecasts tend to remain on one side of the regression line, when the variance of estimate of the regression equation increases, or when the coefficients in the regression equation show a progressive change. After such a tendency is discovered, the forecaster keeps his equation as nearly abreast of the population shift as possible. This is done by dropping off some of the early years of the snow course and water-yield records, basing the regression only on more recent years. And from then on a "moving" regression is employed, with the earliest year of the series dropped each time a new year is added. This was done with the Snake River data after 1939, as suggested in the column "Degrees of Freedom" in Table 2.

Careful use of techniques like this, combined with close coordination between field men and statisticians, should provide maximum precision from water-yield data, correlated with a single factor in a linear regression. Further precision may sometimes be gained by the use of additional factors, or by fitting curvilinear regressions if they are based on a sound hypothesis.

The Use of Complex Relations

Considering curved regression lines first, it is essential that there should exist a logical hypothesis for curvilinearity, which should also specify the probable shape of the curve. Where no particular mathematical hypothesis can be set up, it may be desirable to fit a quadratic equation to the data. In this case, it is easy, in the course of the analysis, to test the validity of the curvilinear equation by statistical methods.

The use of multiple regressions may often be more profitable than the fitting of curves. As our knowledge of variables that are correlated with water yield increases, we shall want to associate more and more independent variables with the one we need to forecast: variables such as total winter precipitation, as well as the spring water content of snow; antecedent soil moisture, as a measure of deficits of water stored in the soil reservoir; stream discharge during the preceding autumn; spring precipitation subsequent to the snow surveys; and others which have been suggested and are being studied.

Whatever the variables are, they can be added to the regression equation in any desired number and combination of curved and linear relations, as long as enough degrees of freedom are left to provide a reliable estimate of the variance of the forecast. As in the test for curvilinearity, the value of each independent variable can be tested by statistical methods. When, as a result of these tests, the forecaster is fairly certain that one or more of the variables being tried out does not contribute significantly to the precision of his forecasts, the variable may be dropped from further consideration; and, if desired, its place can be taken by a more efficient variable.

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GERONTOTHERAPEUTICS*

THE recent growth of interest in the medical aspects of aging is a natural consequence of the increasing age level of the population. Efforts to widen the healthy middle span of life will decrease the period of senility as well as increase the average life span. The application of scientific and medical research to pediatrics has given such good results that further work, although necessary and desirable, may be expected to reach a point of diminishing returns for the time, effort, and money involved. The next big general problem in the field of medicine, therefore, is the prevention and control of the changes in the human organism brought about by age.

Research work in the field of aging divides itself into four attacks upon the problem. The first and most obvious approach is geriatrics, which consists in the therapeutic treatment of the infirmities and diseases associated with age, irrespective of their origin. The treatment of the aged, or geriatric medicine, has already become one of the major interests of the clinician and the practitioner. Research in geriatrics may be best carried out by the physician in the clinic and in general practice. All fields of medicine contribute to geriatrics, and rapid advancement in this branch has taken place in the past few years. The importance of geriatric medicine will increase with time. Unfortunately, geriatric medicine is a case of locking the stable door after the horse has been stolen. It can alleviate the ills of age, but by the time the physician begins treatment the effects of the aging process are already far advanced. Research in geriatrics may be safely left to the medical profession with appropriate contributory help from the research scientist.

A second phase of aging research is the psychological and psychiatric treatment of the aged. Only skilled psychologists and psychiatrists can investigate this aspect of the problem, which may be called "pychogeriatrics." At best such research, and treatments developed, are only adjustments and compensation processes for an established syndrome. This work will become more important as the average age of the population increases.

The key field of investigation is gerontology, a third phase. Gerontology is concerned with the biology of the aging process, the changes in the tissues with time, and the effects of age on the body as a physical mechanism. Within the past few years this field has developed greatly, and various foundations have subscribed to the work. An understanding of the biology of the aging process is essential to the treatment of the aged in geriatrics, as well as to a successful attack on the control of the aging process involved in the fourth attack on the problem, or gerontotherapeutics.

Gerontotherapeutics is a term invented by Benjamin[1,2] to describe the treatment of the aging process as an entity, the treatment of the individual to slow down and to prevent the development of many of the aspects of senescence. It is the practical application of the results of gerontological research to the human being. It includes the determination of the optimum dosages and treatment of antiaging agents on old animals so as to discover the limits of usefulness and the mode of application of such agents. The final step in gerontotherapeutics is the clinical testing on patients so that the beneficial and useful treatments may be released to the medical profession for general use. Until the present time this phase of the aging problem has been almost totally neglected. Neither men nor funds have been provided for the practical utilization of the scientific discoveries already made in gerontology.

There are at least four elements in the problem of gerontotherapeutics that must be investigated further by appropriate work on old animals and then carried through the clinical stage for human use. The vitamin field is being investigated for therapeutic treatment in geriatrics, but it has been neglected as a preventive measure in gerontotherapeutics. Sherman[3] screened vitamin A on various dosage levels in rats and found that an increased intake up to a certain level increased the life span of rats about 10 per cent. A similar increase on a different strain of animals was also found by the Pauls for vitamin A.[4] On another life form vitamin B_6 (pyridoxin) and pantothenic acid increased the life span from 10 to 25 per cent.[5] A combination of sodium yeast nucleate, pyridoxin, and calcium pantothenate gave an increase of about 46 per cent in the average life in the same research.

It is evident that a complete screening of the various vitamins is necessary, with the establishment of optimum intakes to slow down the aging process. A complete analysis of the work required for the use of vitamins as antiaging factors has been made.[6] In this program investigations on other nutrient factors, such as yeast nucleic acid, should also be carried out. If fed in large doses

* Based on discussions before Section IA—Aging Research, Biological, Medical, Physiological, Sociological Aspects, of the National Conference on Aging, August 13-15, 1950, Washington, D. C.

from birth, yeast nucleic acid has been demonstrated to increase the life span of mice to an extent of about 15 per cent of the average life span.[7] A smaller daily intake shows about a 10 per cent increase of the average life span in old mice.[8, 9]

Hormones have not been effectively screened for their influence on the average span of life, although it has been demonstrated that testosterone[10] and progesterone[11] may show some beneficial effects upon the senescent period. Some excellent work on hormones and the aging process has been carried out by Korenchevsky and his associates. Complete evaluation of hormones in the aging process must still be determined.

The major cause of death in any civilized country may be traced to some form of breakdown of the cardiovascular system. The prevention or elimination of this type of breakdown must be a major objective of gerontotherapeutic research. The Foundation recently formed by the American Pharmaceutical Manufacturers Association plans to undertake work in the geriatric and gerontological phases of this problem. An investigation of the gerontotherapeutic side is also necessary. The use of choline[13,14] and inositol[13,15] to remove cholesterol deposited in the circulatory system in the treatment of arteriosclerosis and coronary thrombosis has reached the clinical stage. Their use to *prevent* the development of cardiovascular breakdown in man is yet to be investigated, although positive evidence has been obtained in animals. The roles of pyridoxin[16] and tocopherol in the prevention of heart disease have still to be evaluated.

The successful solution of the cardiovascular problem would do more to lengthen life than any other phase of the aging problem, unless it were to be the complete solution of the growth factors phase discovered by Carrel and his co-workers.[17] The investigation, identification, and production of the antiaging factors found in plasma will result in the renewal of tissue by growth, which is the final solution of the aging problem. This fourth phase of the problem will take the greatest length of time to develop, but its solution offers the greatest returns. Serological investigations should also be carried out in order to increase the resistance to internal breakdown.

The four parameters discussed will automatically expand with increasing work in gerontology and gerontotherapeutics. Fortunately methods are now known for clinically testing the rate of aging, so that the efficacy of a project in gerontotherapeutics can be verified on human beings in a clinic, as well as upon animals. The rate of healing of wounds[18] and the change of the refractive index of the lens of the eye[19] are functions of physiological age. Therefore, these two tests may be used to evaluate on clinical patients anything that shows up favorably in animal work. This evaluation can be carried out in three to five years instead of waiting for about two hundred years for something to show up in the general population, as many investigators have assumed to be necessary.

In investigations on laboratory animals the healthy life span has been increased by the use of longevity factors instead of increasing the period of senility, as many people who are unfamiliar with the work think is being done. The animals remain healthier, more vigorous, retain sexual virility, and do not exhibit the general debility before death noted in the control, or untreated, animals. This gain in real living is in addition to the increase in the average life span.

Research in gerontotherapeutics is also an indirect method of attacking the cancer problem, for the incidence of tumors increases with age in humans. Animals treated with longevity factors do not develop as many tumors as the control, or untreated, animals. This may mean that the longer the animal lives as a healthy, vigorous specimen the younger the cell types retained by the body, and thus a decreased probability for the development of tumors.

The first major attack on the aging syndrome using the methods of gerontotherapeutics will be by the newly created National Foundation for Anti-Aging Research, Inc., New York City. This organization will carry out large-scale animal screening and clinical testing on the positive vectors hitherto uncovered by gerontology and early gerontotherapeutic research. The objectives of the new foundation include the development of practical and useful antiaging agents that may be used by the general population under the supervision of the medical profession. The foundation will concentrate upon the general improvements of health and the life span at various levels of the population from about thirty years of age up. Improvement in health and life span are inversely related to the age of the patient at the beginning of the gerontotherapeutic treatment. Therefore gerontotherapeutics is essentially preventive medicine.

The increase in the average span of life from such a gerontotherapeutic program is a matter of discussion for investigators in the aging field. The pessimistic ones estimate an increase of average life span in the range of about ten years, whereas the more optimitic believe that there is a good probability of doubling the average life span. Nearly all

agree, however, that man dies too early, and that the average span of life can be increased. The organs of the body are designed for an average length of life equal to approximately twice the present average. If the rate of aging can be reduced, and there is scientific evidence that it can, then the average length of life should approach eventually the upper limits of several hundred years found by Simms[20] in his analysis of death rates at various ages. In order to achieve any scientific objective, money, men with the desired mental outlook and scientific training, and time are needed. There is no field of medical research known today than can offer hope of such rich rewards for the expenditure of such meager sums as gerontotherapeutics, and the goal is certainly worthy of the effort.

Two national factors should also be considered. If we are confronted with a long war, or a series of small wars, it will be necessary for the older age groups to carry out a major part of the production prerequisite to national survival. The older groups can do this if they are well, healthy, and younger than their years! Also, the increasing age level of the population poses two alternatives. In one we have a large number of senile people in poor health who must have medical and nursing care and attention. This condition cuts down on our ability to produce for the abundant life by taking out of production and creation of national wealth a large number of people—both patients and their attendants. If, however, the older age groups are healthy, active, and younger than their years they will continue to contribute to our human resources, which are basically the primary source of our national well-being and economy. Both problems can only be successfully solved by gerontotherapeutics.

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New Books Received

Glossary of the British Flora. H. Gilbert-Carter. xviii + 78 pp. $1.75. University Press, Cambridge, Eng., 1950.

The Atom at Work. Jacob Sacks. xii + 327 pp. Illus. $4.00. Ronald Press, New York. 1951.

Mathematical Engineering Analysis. Rufus Oldenburger. xiv + 426 pp. Illus. $6.00. Macmillan, New York. 1950.

Fifty Years of Forestry in the U. S. A. Robert K. Winters, Ed. x + 385 pp. Illus. $4.00. Society of American Foresters, Washington, D. C. 1950.

Crystal Growth. H. E. Buckley. xv + 571 pp. Illus. $9.00. Wiley, New York. 1951.

Plant Embryology. Donald Alexander Johansen. xvii + 305 pp. Illus. Chronica Botanica, Waltham, Mass. $6.00 (reg. ed.); $14.00 (special ed.). 1950.

Tecnologia de los Aceites Vegetales. (Vol. 1) Pier Giovanni Garoglio. xiv + 1,284 pp. Illus. $25.00. Universidad Nacional de Cuyo, Mendoza, Argentina. 1950.

The Engineering Method. John Charles Lounsbury Fish. vi + 186 pp. Illus. $3.00. Stanford University Press, Stanford, Cal. 1950.

Radiation Monitoring in Atomic Defense. Dwight E. Gray and John H. Martens. vi + 122 pp. Illus. $2.00. Van Nostrand, New York. 1951.

The Frog. Robert Rugh. x + 336 pp. Illus. $4.25. Blakiston, Philadelphia. 1951.

Early Embryology of the Chick. (4th ed.) Bradley M. Patten. xiii + 244 pp. Illus. $3.50. Blakiston, Philadelphia. 1951.

The Smut Fungi. George William Fischer. x + 387 pp. $6.00. Ronald Press, New York. 1951.

Airplane Aerodynamics. Daniel O. Dommasch, Sydney S. Sherby, and Thomas F. Connolly. xiii + 520 pp. Illus. $6.50. Pitman, New York. 1951.

[*Continued on advertising page xii*]

BOOK REVIEWS

SOCIAL PSYCHOLOGY

Measurement and Prediction. Volume 4 of "Studies in Social Psychology in World War II." Samuel A. Stouffer, Louis Guttman, Edward A. Suchman, Paul F. Lazarsfeld, Shirley A. Star, and John A. Clausen. x + 756 pp. $10.00. Princeton University Press, Princeton, N. J. 1950.

WHEN Stouffer and his colleagues in the Army's Information and Education Branch formulated plans for publication of their wartime work in social psychology they projected a four-volume series. The series is now complete. Collectively it represents the outstanding contribution of the times to social psychology. The first two volumes are a gold mine of information on the characteristics and attitudes of American soldiers in World War II. Volume 3 summarizes the branch's experimental studies of the effects of propaganda and mass communication. Volume 4 describes the branch's principal methodological contributions to measurement and prediction in social psychology and sociology.

Scale analysis as developed by Louis Guttman is the subject of the first group of chapters. A scale, in Guttman's sense, is possible when the items of a test or questionnaire can be so ordered that persons who give a favorable answer to any particular item will all have higher ranks on the variable being measured than will persons who answer that item unfavorably. When such an order is possible the number of items which a person answers favorably (his scale score) also tells exactly which items he answered favorably. The score thus defines precisely the person's attitude. Stouffer gives a simple example of the cumulative type of item necessary for such a scale.

1. Are you over 6 feet tall? ...Yes ...No
2. Are you over 5 feet 6 inches tall? ...Yes ...No
3. Are you over 5 feet tall? ...Yes ...No

Answering "Yes" to any of these items requires that all below it also be answered "Yes." Thus the number of items to which a person has answered "Yes" also tells exactly which ones have received that answer.

In attitude measurement, the items are more likely to be of the type:

> If you had a son, would you want him to have a certain amount of Army training during peacetime, or not?
>
> ...Yes, I'm almost sure I would
> ...Yes, I think I would, but I'm not sure
> ...No, I probably would not
> ...No, I'm sure I would not
> ...Undecided

Under practical conditions, perfect scalability is not expected, and, for that matter, seldom even approximated. For in most attempts at attitude measurement the items cannot be ordered in the same way that the three questions concerning height were ordered, for the usual collection of attitude items will not be of the necessary cumulative type. Sometimes, however, a set of items is scalable, and sometimes a subset of items from an attitude questionnaire can be scaled. Determination of whether a scale is present is greatly facilitated by an ingenious mechanical "Scalogram Board," which allows rapid rearrangement of the sets of answers given by each respondent or given to each item. Since a distinctive pattern on the Scalogram Board indicates a scale, the determination can be made visually. The degree of approximation to a perfect scale is then obtained by a formula which measures how well the actual distribution of responses can be reproduced from the scale scores.

When a set of items can be scaled, a small number of them, sometimes only three or four, serves as an efficient means of classifying respondents along a unidimensional attitude continuum.

The other technique described in detail is latent structure analysis. This method, developed by Paul A. Lazarsfeld, is a generalization of factor analysis to handle qualitative data. The attitudes in latent structure analysis are inferred from the relations among the answers to a set of items somewhat as the factors in factor analysis are inferred from the correlations among a set of tests. In this respect latent structure analysis differs fundamentally from scale analysis, which defines the attitude wholly in terms of the item responses.

Latent structure analysis is by no means fully worked out, but the logic is given in fair detail, and computation methods for some of the simpler cases are presented and illustrated.

The final five chapters present two detailed case studies in the prediction of behavior. Readers who may not be interested in the earlier discussions of measurement will find in these chapters details of the branch's work on psychoneurotic screening and the prediction of soldiers' postwar plans. They will also find startling evidence of one of the major difficulties of attempting to construct a psychoneurotic screening device—the variability of psychiatric classification. For example, during the month of August 1945 the percentage of men called for preinduction examinations who were rejected for psychiatric reasons ranged from 0.5 per cent at one camp to 50.6 per cent at another. Furthermore, the specific diagnoses given to psychiatric rejects, even when they came from neighboring geographical regions, also varied tremendously. At Fort McClellan, Alabama,

2.8 per cent of the psychiatric rejects were classified as psychoneurotics; at Fort Oglethorpe, Georgia, 73.9 per cent were called psychoneurotics. Constructing a paper-and-pencil predictor to use in a nationwide effort to select the men whom the psychiatrists should examine with particular care presents very obvious difficulties in view of such variability of classification and diagnosis. Nevertheless, using scale-analysis techniques, the branch was able to make up a paper-and-pencil questionnaire of 23 items and to establish a cutting score which selected 31 per cent of all men examined but which included within that limited group 81 per cent of all those who were rejected as psychoneurotics. Incidentally, the numbers of men identified by the test as worthy of particularly careful examination did not differ from station to station nearly as widely as did the rejection and diagnosis rates given by the psychiatrists.

As is evident from the summary given above, the book is not unitary; different topics are discussed by different authors. Yet the ideas discussed and the methods described are such that any reader interested in the development of a social *science* will give it a high rating.

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FUNGI, EXCEPT SMUTS AND RUSTS

Diseases of Cereals and Grasses in North America. Roderick Sprague. xvi + 538 pp. Illus. $7.00. Ronald Press, New York. 1950.

THOSE who have followed with interest the career of Dr. Sprague will not be surprised at the publication of this book. It is the culmination of many years of effort devoted to the study of North American grasses and their diseases. By odd coincidence, the book reached this critic on Dr. Sprague's fiftieth birthday (January 10).

The grass family (Gramineae) is probably one of the most widespread, variable, and economically important families of plants on earth. Grasses are found in forests and on plains, on deserts and in lakes, in torrid and in arctic regions. There are over a thousand species of grasses in the United States alone. Grasses are directly or indirectly the principal food for animal life, and the economy of large regions is directly affected by the magnitude of each year's crop.

The ubiquity and diversity of grasses seem to be one of the main reasons for the diversity of fungi occurring on them. By rough count, the number of grass species listed in Seymour's *Host Index of the Fungi of North America* exceeds 800, and, in most instances, several to many species of fungi are reported to occur on each host. By a count made by Sprague and referred to in one of his earlier publications, the number of combinations (grass hosts + fungi) given in Seymour's index is about 2,820. In the same paper, Sprague reports that in one of his unpublished lists concerned with the Western area alone, the number of combinations is 3,257.

Obviously, when confronted with the task of fully describing the multitude of fungi occurring on grasses, most mycologists would feel unable to spare the required effort. Dr. Sprague, however, appears to have drawn on his vast store of energy and has completed a goodly part of the task before him. He has wisely refrained from dealing with the many rust, smut, bacterial, and virus diseases of the Gramineae, although this critic suspects that he originally intended to deal with them as well. The fact that studies of these groups of plant diseases have been made by other workers, and the results published within the past two decades, may have deterred Dr. Sprague from the additional gigantic effort.

In this reviewer's opinion, Dr. Sprague's book, to which he modestly refers as only a manual, is a very worth-while addition to the library of any worker concerned with problems involving the Gramineae, as well as to the libraries of scientific institutions. The information published in it fills a wide gap in our knowledge. It "contains discussions of 384 species and subcategories of parasitic fungi as well as a number of associated saprophytes found growing in the region." Each fungus is discussed fully, adequate attention being given to synonymy, to technical description of the fungus itself, to its host range or habitat, and, in the case of parasitic species, to the description and control of the associated disease. In some instances the lists of hosts and loci of collection seem overlengthy, suggesting to the reader that the fungus concerned is omnivorous and possibly could be referred to as such. In other instances the common name for a disease seems somewhat vague. These possible faults are, however, of little importance, and they do not detract from the value of the work.

Both the author and publishers are to be congratulated on the appearance of the book. The paper is of high quality, the type is clear, and the illustrations (of which more seem to be needed in the first half of the book) are detailed and very good. A possible improvement might be to add to the title on the book cover the rider, "Fungi, except smuts and rusts," which appears on the jacket and title-page.

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UNDERSTANDING THE RUSSIANS

Soviet Psychiatry. Joseph Wortis. xv + 314 pp. $5.00. Williams & Wilkins, Baltimore. 1950.

IMPORTANT to American psychiatry and psychology is a detailed report on Soviet psychiatry by the assistant clinical professor of psychiatry at the New York University College of Medicine.

The first item is an apology by the publisher for presenting something about Russian science; at the end the author wryly comments that the *Journal of the American Medical Association*, which abstracts 250 of the world's medical journals, reports nothing from the lively

Russian field. In between Wortis proves that this carries something a bit too far; he had to learn Russian in order to do it. One wonders now if the Russians will translate the book, for they have no definitive summary like this of their own work.

There is something here for physiologists, sociologists, and the gamut between. Writing in the friendly but objective tone which he had to maintain in order to get his information, Wortis remains expository throughout; he is succinct but neither stylistic nor hortatory; documentation is good. Where he presents his own viewpoint, as with regard to the compatibility of American and Russian psychiatry, he does so with quotations that speak for themselves.

Chapters pertain, consecutively, to the influence of dialectical materialism upon Soviet psychiatry and the fight since 1917 for a distinctively Russian psychology, the enormous influence of Pavlov and his dynamic physiology, the organization of psychiatric care, low official regard for psychoanalysis and the stress in treatment upon rational consciousness and physiological relief and wholesome work activity, the development of child psychiatry and clinical practices (well ahead of theory, as here), preferred treatments of the psychoses (especially schizophrenia), ideological and pragmatic emphasis upon work in therapy, education and research in psychiatry in the Soviet Union, the prevailing cultural and sociological features of practice (apparently especially successful in coping with juvenile delinquency), and contrasts between the roles of psychiatry in the USSR and the USA.

Appendices are translations of Soviet self-criticisms in education (of "pedology"), and in psychology and psychiatry (of idealism, metaphysics, and nonpartisanship), with a summary of their five-year plan in medicine and an essay on courage from a Russian educational journal. Wortis has done a good job and proved the need, for mutual advantage, of scientific interchange.

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AN INVENTOR REMINISCES

Father of Radio. The Autobiography of Lee de Forest. x + 502 pp. $5.00. Wilcox & Follett, Chicago. 1950.

THE book under review tells the story of the ups and downs in the life of the inventor Lee de Forest. In his introduction he says:

> I believe I may, without immodesty, claim to know better than any man, living or dead, the natal circumstances and early history of the things we call Radio and Television. It is therefore with a sense of obligation, as well as pride, that I endeavor in the pages of this book to share my great store of personal recollections with my readers. Here for the first time are revealed interesting chapters of history previously known only to myself and intimate acquaintances.

The beginnings of wireless communication were in the field of telegraphy. The classical researches of Hertz in 1887 on the production of electric waves attracted numerous investigators into this field. The success of Marconi in 1899 in sending telegraphic messages across the English channel, and his later bridging of the Atlantic Ocean in 1901, drew public attention to the value of this new means of communication. Lee de Forest graduated from Yale in 1896, and when he obtained his Ph.D. degree in 1899 the title of his thesis was "The Reflection of Hertzian Waves from the Ends of Parallel Wires," which pointed in the direction his later career was to follow.

De Forest had always been interested in music, and his early work was directed toward replacing the Morse code of dots and dashes by musical notes. From this the next step was to the transmission of the speaking voice. His invention of the three-electrode tube made this possible. The details of his work and his many disappointments are interestingly set forth in this book. De Forest was interested in poetry as well as music, and occasionally dropped into verse. The book gives a number of examples of this.

In addition to experimental difficulties, when some of his patents began to become valuable, Dr. de Forest became involved in litigation; but the stormy days of his life described in this book close with a clear sunset at his home in Hollywood.

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FORENSIC SCIENCE

An Outline of Scientific Criminology. Nigel Morland. 284 pp. Illus. (No price given.) Philosophical Library, New York. 1950.

SCIENTIFIC criminology is the loose but rather dignified appellation given to those techniques and procedures which assist society's legal arm in its business of identifying and apprehending the participants in crime. The term covers the many branches of applied science that lend themselves to forensic employment for the purposes of criminal investigation. Actually, it describes the scientific arsenal wherein the weapons of the fight against all kinds of crime, from murder to counterfeiting, are stored. Thus, scientific criminology is not an independent science, nor even a special area of knowledge, but a framework of purpose within which various disciplines operate in their own ways to achieve a common goal.

This volume by the British crime writer, Nigel Morland, provides us with a survey of scientific criminology. Simply written, directed at neither the practicing investigator nor the casual reader, it ranges over the entire field and provides a panoramic view of an important but little-known area of scientific application. In a lucid manner that makes for easy reading and swift comprehension, Morland presents the essentials of the various contributions made to detection, investigation, and apprehension from such widely separated fields of inquiry as fingerprinting and blood chemistry. Sketchily, but without sacrificing accuracy, he ranges

over medical jurisprudence, forensic ballistics, cryptography, toxicology, microscopy, and other adjuvants to police and detective work. In all respects, the outline thus presented is fast-moving and lively. It is interspersed with interesting examples of content drawn from Morland's own experiences and the records of outstanding court cases. Also, the photographs that have been chosen to illustrate the text are apt. And yet, this is a work which leaves the reader—or at least this reader—dissatisfied.

The reason for my dissatisfaction with Mr. Morland's book is the feeling it leaves that it was written in a perfunctory fashion and without a philosophy or point of view. By this I mean that the reader who hopes to find herein more than an unusually engrossing description of the tools and materials employed by the legal side in its war against crime will be disappointed. I think this comes from the fact that the book neglects to consider the offender as a human being, and so fails to include a whole area of knowledge—the psychology of the criminal—which more than any other reveals him for what he is and leads to his eventual apprehension. Perhaps Morland avoided this topic deliberately; but I think it makes his book less useful and certainly less important than it could have been.

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INDIAN CASE HISTORY

Culture in Crisis: A Study of the Hopi Indians. Laura Thompson. xxiv + 221 pp. Illus. $4.00. Harper, New York. 1950.

SOCIAL scientists might well follow the naturalist in describing life as a process in which an organism is attempting to create a set of conditions within which to carry out its urges. For this description seems to be as accurate an account of human beings as they go about creating social organizations as it is for a bird building its nest.

In Dr. Thompson's illuminating and multidimensional study, we have a case history of a small group of persons (less than 4,000) who had, as the author points out, developed over the centuries a social system which was structurally and functionally adequate to meet their needs. An outstanding contribution of this study is the recognition throughout that the adequacy of the social organization the Hopi had created through time was due to the fact that their basic world view was dynamic in both a logical and an aesthetic sense. Their value systems, their rituals, their language as brilliantly analyzed in a special chapter by the late Dr. Whorf, and their whole symbolic structure were their creation. All these gave meaning to their living and provided sets of assumptions which were for them adequate to meet the occasions of life and the emergence of new situations that arose within their indigenous environment.

We know from a variety of evidence from psychology, history, and ethnology that ideas are meaningful only insofar as they are personal, derived from one's own experience and tested in one's own experience. Since the Hopi social organization was their own creation, the imposition of new standards by the white man was bound to disturb radically the nice balance of conditions within which the Hopi were carrying out the urges and capacities that characterized them as human beings. This study brings out with great insight the unpredictable consequences of the introduction of even one small characteristic or artifact of an outside culture. And from this point of view alone the analysis of the Hopi has profound implications for modern times, warning us implicitly as it does, for example, that our Point Four program is apt to create more anxieties than it would allay if it carries with it any imposition of cultural norms, or if it attempts to impose ways of life that are too advanced for the full participation of individuals whom we are in good faith trying to help.

The Hopi define the word *hopi* as "peaceful, good, happy." The development of peaceful, good, and happy personalities has been the ideal of the Hopi for centuries. Hence the report of the disintegration of the Hopi culture brought about through early contacts with the white man, through missionaries, and through unwise governmental policies is unusually poignant. It is therefore especially encouraging to find that this particular study was designed to give a basic understanding for government administration and was encouraged and made possible by the U. S. Office of Indian Affairs. This new and enlightened official policy was due in large part to the vision of John Collier, Commissioner of Indian Affairs from 1933 to 1945, who provides the foreword to this volume and quite properly states that studies such as this can be "discovering instruments" which will deepen our "sense of society" and enable us to see how and why societies are more than mere materialistic agglomerations.

The book contains a number of excellent photographs which help the reader feel what the words of the book convey.

HADLEY CANTRIL

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LIGHTNING

The Flight of Thunderbolts. B. F. J. Schonland. 152 pp. Illus. $3.00. Oxford University Press, New York. 1950.

THIS book is written in a pleasing style and should be welcome reading for the general public. The best chapters are those where the author relates his own original, splendid, pioneering work with regard to the step and dart leader mechanism of the lightning strokes and atmospherics. Of general interest are the chapters on the concepts of lightning by earlier civilizations, extending to the contemporary witch doctors of the Bantu tribes in South Africa. The experiments of Benjamin Franklin and his invention of the lightning rod system of protection for buildings and houses are well

described. It is gratifying that the author debunks the rather prevalent opinion that pointed lightning rods can prevent lightning strokes to a structure by virtue of silent discharges.

In general, the facts given in the book follow most recent findings and should therefore be useful to the student of this subject. There are a few rather arbitrary statements which do not agree with general practice or have not yet been proved correct, such as the pilot streamer, the diameter of the lightning stroke, the protective angle required for efficient protection of houses and buildings, and some others. To enable the student to draw his own conclusions on such subjects, it would have been well to include bibliographical material.

There has been relatively little written on lightning outside of technical papers. This book, therefore, should be a valuable addition for study of this difficult and highly technical subject, both for the general reader and the student. Some of the technical points are covered rather completely; others are sufficiently indicated to lead to further study. The author is to be congratulated on having covered such a large field in the relatively short space of 148 pages. Enough diagrams and plots are included to explain the more technical points of the story in rather elementary fashion.

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LEARNING THEORY

Personality and Psychotherapy. John Dollard and Neal E. Miller. ix + 488 pp. $5.00. McGraw-Hill, New York. 1950.

THE authors start from the premise that if neurotic behavior is learned it can be unlearned. This assumption leads to the conclusion that the principal theoretical base for psychotherapy is a clear theory of learning. The book is devoted to the development of a theory of learning in a form applicable to clinical practice and to illustrations of such application.

The learning theory used is the authors' own variant of Hull's reinforcement theory, without Hull's mathematical extensions which make the basic datum of observation a series of reinforcements. Instead of this a simplified theory which makes the basic datum the single reinforced association is adopted, and there can be no question that this simplification makes the theory far more readily usable in clinical practice. Practice almost never offers the series of repetitive reinforcements required for the use of Hull's postulates.

The four concepts in terms of which Dollard and Miller describe learning are *drive, cue, response,* and *reinforcement.* Drives are innate or learned. Strong stimuli act as drives, and furnish the underlying determiners of activity. Cues are the adventitious stimuli present with the responses engendered by drives. When a cue-response sequence is followed by the reduction of drive or reinforcement, the cue becomes an occasion for the response which it accompanied. This is how neurotic behavior is learned, and this also explains how psychotherapy removes neurotic behavior. When cues are repeated and responses occur, but without reinforcement, extinction follows. The presence or absence of reward or reinforcement is therefore the primary guide to learning.

With this theoretical stand the authors illustrate in great detail and in great variety the ways in which neurotic behavior originates and is sustained, or is reduced through psychotherapy. The reinterpretation of Freud's pleasure principle in terms of reinforcement adds much to its utility. By their use of theory the authors can furnish a naturalistic account of repression which makes repression far more understandable and its effects more predictable. The reinterpretation of transference in terms of generalization is a similar improvement in a somewhat vague Freudian concept. The phenomena of conflict become more easily described and understood in terms of learning theory than they were in the dramatic terms of Freud. There can be little question that the authors' intention to provide a systematic theoretical basis for psychotherapy is in general successful, and that both teaching and practice will benefit from their richly illustrated exposition. Many of their illustrations come from a case record of an extended psychoanalysis.

Much remains to be done in the construction of learning theory before psychologists will be in agreement on details. There are a number of gaps not resolved by Dollard and Miller. When all learning is held to be dependent on reinforcement in the form of tension reduction, they have difficulty in explaining how new drives, which represent tension increase, get learned. But, in general, for the purpose of directing and informing clinical practice, their theory readily demonstrates its usefulness, and represents a great advance over the earlier psychoanalytic explanations. Neurotic symptoms are adopted because they reduce misery. They are abandoned only when new and more tolerable ways of reducing or avoiding misery can be substituted. The role of language in therapeutic learning and the use of language by the therapist to lead the patient to extinguish fears, establish discriminations, reasoning, foresight, hope, and planning are spelled out in great detail. The book should be a very welcome text.

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PLANTS OF A CORAL ATOLL

Plants of Bikini. William Randolph Taylor. xv + 227 pp. Illus. $5.50. University of Michigan Press, Ann Arbor. 1950.

THIS is the magnificent kind of scientific book that was so characteristic of a century ago, when science was so new and appreciated that it did not have to be boiled down and desiccated for technical consumption or infinitely diluted and mixed with sugar for popular dosage. In this blasé age such books are so rare

as to be almost nonexistent. Though, obviously, the sales attraction of the atomic bomb interest in Bikini was not overlooked, this book is an honest and extremely effective attempt to present a body of scientific information in the most complete and authoritative way possible. The author and the University of Michigan are to be congratulated.

When, through the farsightedness of certain scientifically trained naval officers, a biological survey of several atolls of the northern Marshall Islands was planned as a part of Operation Crossroads, it was necessary to choose a botanist who had broad experience and interests. The task entailed collection and study of all groups of plants and the description of vegetation from practically desert land conditions to reefs and deep water that could only be reached by dredging. A better choice could not have been made than William Randolph Taylor. Because of his wide previous experience in tropical waters, and his position of solid authority on the marine algae—by far the most numerous and most difficult group of plants to be found on a coral atoll—the expedition was indeed fortunate that he could be induced to accompany it.

The book is divided into four principal parts. After an informative historical summary there is a careful descriptive account of the vegetation. First there is a generalized description of both land and marine features, then a detailed treatment of each of the four atolls surveyed—Rongerik, Rongelap, Bikini, and Eniwetok. Special emphasis is given to the fact that, in spite of the name, coral reefs are, in reality, a very interesting type of vegetation. A great part of the actual calcareous material, and much of the cement that holds the mass together, are of massive coralline algae, principally *Porolithon*. The effect of extreme insolation is suggested as one of the controlling factors in the limited composition and simplicity of this vegetation. In general, the author avoids the pitfalls incident to interpretation of vegetation and confines himself to straightforward description. Incidentally, he provides one of the very few available investigations of the microvegetation of atoll soils.

The second part is a systematic study of the plants found. It is of interest that nineteen new algae were found, but, as expected, no new higher plants.

The next important section is a bibliography, not confined to articles on the Marshall Islands, but evidently covering all papers consulted in the course of the investigation. This is a valuable source of information on the literature of the Marshall Islands, coral reefs, and tropical marine algae.

For all except the strict botany student, and perhaps even for him, the last section of the book is by far the most interesting. It is the series of 79 plates, consisting of maps of the four atolls and 144 superbly reproduced photographs, obviously chosen to clarify and emphasize the text. There are views of the vegetation, close-ups of the individual plants, and even microphotos of sections of some of the algae. In addition there are two beautiful color photographs of the reefs exposed at low tide, showing the rich coloration of coralline algae and corals. Seldom has a more satisfactory or more beautifully illustrated scientific book appeared.

It is customary in book reviews to mention also the points that impress the reviewer unfavorably. In this book, however, such are hard to find. One might only point out two instances of the results of the editorial passion for eliminating even standard abbreviations. Beauv. is expanded to Beauvais rather than Beauvois, L.f. to Linnaeus *fils* rather than the Latin *filius*, and Bull, which is not an abbreviation at all, nevertheless is expanded to Bulliard. The authority for *Terminalia litoralis* is Seemann rather than Linnaeus.

It may be mentioned in passing that the publication of this book is of especial interest because it so opportunely fits into an extensive study of the ecology of coral atolls being sponsored by the Pacific Science Board of the National Research Council. Of no other atoll is the vegetation so well known, now, as that of Bikini and its neighbors.

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PSYCHOLOGY IN HISTORICAL PERSPECTIVE

Feelings and Emotions. Martin L. Reymert, Ed. xi + 603 pp. Illus. $6.50. McGraw-Hill, New York. 1950.

THIS book contains the proceedings of the Mooseheart Symposium on Feelings and Emotions held in October 1948, at Mooseheart, Illinois, and the University of Chicago under the auspices of the Loyal Order of Moose. The volume is edited by Martin L. Reymert, director of research for the Moose, and general chairman of the symposium. In addition to the welcoming addresses, etc., there are some forty-seven contributions by a list of distinguished American and European scientists.

It is not a volume for the lay reader. The papers are technical in nature and are presented for a professional audience. At the professional level, however, every specialist interested in the field will want it for his library. The level of performance varies but is in general excellent, the eminence of the authors guarantees interest in their contributions, and the subject is well covered. A few names that should be there are missing (I think particularly of Hebb, Landis, P. T. Young, and Selye); the European section is somewhat disappointing; but the only real criticism to be raised is that one usually associated with "name" symposia—great men can always be counted on to speak, but not relied upon to speak to the subject. Some of the papers are tangential to the topic, and a few definitely unrelated to it. Nevertheless, even the obvious digressions are interesting and worth while.

The book offers some interesting historical perspectives. The original Wittenburg College symposium on feelings and emotions held in 1927, also under Dr.

Reymert's direction, provides some contrasts. By 1948 the major strength of America in physiological and behavioral psychology is clearly evident. The European philosophical approach seems to have yielded little. Phenomenology (to the reviewer's regret) is all but dead. Present-day psychology seems satisfied with the pedestrian accumulation of proximate knowledge rather than attempting the overnight solution of ultimate problems.

Particularly interesting is the fact that in 1927 a group of eminent psychologists would all be interested in and have something to say about feelings and emotions. Today, with the tremendous development in the subject, feelings and emotions have become but one special aspect of an infinitely broader field. It is still a healthy field, however, and readers of this symposium will have concrete evidence of its health and productiveness.

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THE FABULOUS MONOCEROS

Studies in Muslim Iconography. I, *The Unicorn.* Richard Ettinghausen. ix + 209 pp. + 48 plates. $3.00. Freer Gallery of Art, Washington, D. C. 1950.

THIS study in the history of the belief in a unicorn, an animal of the East, of fierce habits, possessed of a horn embodying remedial and magical powers, is one of the finest pieces of scholarship published in years. Because of its theme, comparison with a somewhat older book, Odell Shepard's *Lore of the Unicorn* (published in 1930), is quite inevitable. It is also to some extent justified, for the two works may be regarded as companion volumes, treating two aspects of the same idea. Shepard's book was devoted to what for the sake of distinction may be called the "Christian" unicorn; Ettinghausen's study is concerned with the idea of the unicorn in Muslim literature and, specifically, with its pictorial representation in Mohammedan books and Muslim works of art.

Both branches of the unicorn myth ultimately go back to the Indian rhinoceros, of which uncertain reports reached the Western countries at an early time. But, because there was so much emphasis on the horn and its alleged powers, the animal and its horn became two separate things, with the animal itself quickly assuming a secondary place. Consequently, the horns of other animals could intrude upon the scene, leading to a confusion which is difficult to disentangle even in retrospect. In the Christian North the intruding "horn" was the tusk of the narwhale, which finally caused shrewd apothecaries to distinguish between *unicornum falsum* (narwhale tusks) and *unicornum verum*, the latter being sometimes true rhinoceros horn but more frequently mammoth tusks.

In the Muslim countries, the intruding "horn" was, as pictorial representations indicate, narwhale tusk on rare occasions; it was usually walrus tusk, for reasons which Ettinghausen has traced with great care. And whereas the Christian countries settled for a generally equine shape of the mythical animal, there was no such uniformity of concept in the Mohammedan countries. They called the animal (mostly) by the name of *karkadann*, which is also the name for the rhinoceros. But only very rarely, and quite late, does a pictorial representation show any resemblance to the rhinoceros. Many illustrations, if it were not for the horn, would be taken as attempts to illustrate antelopes. There are bovine, leonine, and canine "unicorns," the bovine shape being probably influenced by copies of the bas-reliefs on the Ishtar Gate which are meant to portray *rimi* (Hebrew *Re'em*) or *Bos primigenius*.

The large number of representations showing a horned canine are probably due to a linguistic confusion. In old manuscripts where diacritical marks are lacking, a certain word may be read either as *gurg* or as *karg*. The former means "wolf," the latter "rhinoceros." Of course *gurg* was the more familiar word. "To make the issue even more confusing the text is nowhere precise enough to enable the reader to choose between the two. In the stories of Gushtāsp and Isfandiyār the word is rhymed with *suturg* (large) and *buzurg* (big), thus pointing to *gurg* (wolf), and in the accounts of Iskandar and Bahrām Gūr, with *targ* (helmet), *tagarg* (hailstone) and *marg* (death) indicating the form *karg*" (p. 37). The names just mentioned are those of the four heroes credited with having accomplished the nearly impossible feat of killing a *karkadann*.

One fact that surprised this reviewer is the almost insignificant amount of cross-influence between Christian legend and Mohammedan lore, especially since both stem from the same or closely related classical sources. But in both forms the end of the legend was quite similar. In the Christian countries the unicorn myth began to fade when the rhinoceros itself became known, and (in consequence of its appearence?) the pharmaceutical value of its horn was doubted. As for the Muslim countries, Ettinghausen says in conclusion:

"In the eighteenth century, al-Qazwīnī manuscripts of inferior quality, and thus destined for the simple and impecunious, showed illustrations of the karkadann, in which a kind of dreary resemblance to the rhinoceros emerged. The text, of course, still tells the old tales and superstitions, but the miniatures have now nearly caught up with the actual animal. The encounter with reality is, however, disenchanting. The ferocious and yet impressive character of the old monster has gone and all that remains is an immense and unprepossessing hulk of a body. No new ramifications of the age-old myth could possibly grow up around this sort of an animal" (p. 162).

The many plates admirably illustrate the growth and the ramifications of the myth while it still was vigorous and undulled by acquaintance with reality. There is a bibliography of 282 titles and a good index. Although the primary appeal of the work is to historians of science, it should also be of interest to zoologists. And not the least virtue of the book, to my mind, is that it can be read with pleasure by any literate person interested in the history of a thought and a belief.

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STUDY IN ECOLOGY

Adaptation and Origin in the Plant World: The Role of Environment in Evolution. Frederic E. Clements, Emmett V. Martin, and Francis L. Long. xii + 332 pp. Illus. $6.00. Chronica Botanica, Waltham, Mass. 1950.

RESULTS are here presented posthumously of work begun about the turn of the century on the problem of ecological adaptation in relation to evolution. Two of the authors died in 1945, and work which was planned for four volumes was thus brought to a close. One volume on coastal dune gardens at Santa Barbara had been published. This present volume reports on adaptation in controlled gardens at Santa Barbara and at Pikes Peak and includes in condensed form some of the material on convergence and conversion of species which was to have filled a full volume. One of the tragedies of life is the failure of the human organism to survive long enough to complete long studies. A reviewer's task is never easy, but review of compressed and unfinished works is particularly difficult.

In general there are descriptions of the installations at each of the stations and of the responses obtained under the varied conditions created. Variables which were dealt with were soil, nutrients, light, competition, and, by transplanting from place to place, total climate. The transplant series were very extensive. Plants were moved about over quite wide ranges. Pikes Peak, especially, gave excellent opportunity to move plants over great vertical distances, with consequent large temperature changes.

The authors' major conclusion, it seems, is that the origin of all new forms may well prove to derive from environmental forces, and that this is accomplished through adaptation rather than variation and selection. As they remark: "While this view has much in common with that of Lamarck and of Waagen and their followers, notably the paleontologists, it differs in its endeavor to harmonize all known processes of change on the sole basis of ecological measurement and experiment" (p. 165).

The problem attacked is an immense one, and the time, effort, and ingenuity expended were enormous. Lath houses of all sorts; movable and fixed tents for varying lengths of day; dry soil, wet soil, and heated soils; and various devices for measuring transpiration—all were created and worked with for years. Yet the feeling intrudes all through that the problem was too large, the techniques not yet well developed, the "controls" not really controlled, and the variables more variable than the authors realized. Soils are rather simply described, waterings were often haphazard, "nutrient control" sometimes consisted of adding a tablespoonful of vigoro!

The book is profusely illustrated and contains numerous tables and graphs to illustrate conditions and findings. The style is vigorous, although the irritating ecological jargon (a variant becomes a *variad*, habitat becomes *ece!*) destroys ease of reading. What do ecologists gain by retreating into mumbo jumbo? Why is ecogenesis, "meaning born in the house," "uniquely appropriate for designating all evolution in which the motive force is derived from the environment" (p. 165)? Is the environment like a house and the plant like a man in the house, or are the ecologists losing themselves in the pleasant pasttime of coining words?

Fundamentally this is a pioneering work and incomplete. It represents an interesting study of the effects of environmental factors on forms of plants, and it is a valuable record whether one agrees with the authors or not.

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ANIMALS OF THE SOUTHWEST

Our Desert Neighbors. Edmund C. Jaeger. x + 239 pp. Illus. $5.00. Stanford University Press, Stanford, Cal. 1950.

THIS book was written to acquaint the "thousands of new human immigrants" to the desert areas of the Southwest with their animal neighbors. After an initial chapter in which the unsuspected abundance of wildlife within the limited radius of a grand old Joshua tree in the Mohave Desert has been exposed, each chapter is devoted to a single animal or group of closely related animals. The first sixteen are about mammals, then a like number about birds; three are devoted to reptiles, and one to arthropods. Each is an intimate sketch drawn for the most part from the author's many years of desert experience. Realizing that most desert mammals are nocturnal, one is impressed with his familiarity with them. The sketches are short, averaging five or six pages in length. For one whose interest is more than superficial some of them seem too short. But a list of selected references is given; from it one can select more exhaustive works.

Although written for the general reader, the book has been done with scientific accuracy. Most of the animals are identified by scientific names, the derivations of which are so well explained that the reader is interested rather than bored to learn, for example, that the author classifies the piñon jay as *Gymnorhinus cyanocephalus*.

The book is attractively bound, with line drawings of desert animals on the outside covers. The end papers are a map of the desert areas of North America, with an explanation of their characteristics. There are fifteen full pages of photographs, excellently reproduced, and frequent line drawings as chapter headings. One wishes that the photographs had been more logically arranged, however. It is disconcerting to find a striking photograph of the desert bighorn facing the title-page of the chapter on the desert hare, ornamented as it is with a line drawing of that animal, to mention but one instance. In other respects the book is a fine example of good printing and effective page arrangement.

Our Desert Neighbors should interest all, whether desert dwellers or not, who appreciate the combination of good writing and scientific natural history. Used in conjunction with Jaeger's earlier "handbook," *The*

California Desert (1933), which deals especially with desert ecology and plant life, it provides an excellent introduction to the desert and living things of the desert.

HAROLD B. HITCHCOCK

Department of Biology
Middlebury College

BRIEFLY REVIEWED

Noses. Harold M. Holden. 252 pp. Illus. $3.50. World Publishing Company, Cleveland and New York. 1950.

AN EXHAUSTIVE and fascinating work on the nose in psychology, literature, art, plastic surgery, folklore, and anthropology by one of the country's foremost plastic surgeons. The author quotes Napoleon as follows: "When I require a man for head work, I always take one with a big nose if I can find one with the necessary qualifications. He breathes boldly and freely, and his brain, heart and lungs are cold and clear. In my study of human nature, I have always found that a long nose and a good head are inseparable." With a multitude of similar quotations, the reader is led through a galaxy of superstitions about the nose, how it contributes to neurosis, its importance as an index of beauty and ugliness, and the fundamental role it has played in comedy and tragedy. One easily senses that the author has obtained a tremendous amount of pleasure from his literary researches, approaching to some degree the keen satisfaction he has derived from the elation of patients who have been benefited by his skill in plastic surgery. The book is entertaining reading.

MALCOLM H. SOULE

Hygienic Laboratory
University of Michigan

The Chordates. Herbert W. Rand. ix + 862 pp. Illus. $6.00. Blakiston. Philadelphia and Toronto. 1950.

IN HIS preface Dr. Rand tells of the growing difficulty of conducting classes in comparative anatomy caused by the great increase in necessary collateral reading by the student and the mass production of ever larger classes without a corresponding increase in number of instructors. He has therefore devoted years to building this admirable text to alleviate the difficulty. He has done what is humanly possible in the sequence of overlapping topics to keep the horse before the cart, as he puts it.

In the prologue Dr. Rand explains our particular interest in all vertebrates as being due to our realization that we are one of them. The body of the book—the part ordinarily "reviewed"—can be covered by saying that it will be a long time before there appears a better, more logically arranged text—a godsend to instructor and student.

To the lay reader the epilogue is more than interesting, portraying a scientist's estimate of what lies ahead of us if a logical sequence of evolution continues. He believes that, during the short recorded history of man, there has been no evolution in his body or mind, but a great evolution in technocracy. He warns us that any churl can pull a trigger or switch on a radio, which makes it necessary to direct our powers wisely, for the future of the race. Although a "superman" is possible of attainment, the average intelligence is low. We squander tremendous stores of energy, both environmental and human, in periodic outbursts of destruction. "Surgery" may be necessary to remove hopelessly vicious individuals or groups.

CHAPMAN GRANT

San Diego, California

Photography in Astronomy. E. W. H. Selwyn. 112 pp. Illus. $2.75. Eastman Kodak Co., Rochester, N. Y. 1950.

DR. SELWYN, writing from the Kodak Research Laboratories in Harrow, England, explains with a master technician's clarity the photographic problems involved in astronomical photography. Some of the material in this slender volume has been compiled from other (named) sources. "Attention has been confined to general principles" in special problems that make elaborate demands. But the chapter on processing, which is regarded as "the most important section," is detailed and explicit. Other chapters deal with apparatus, properties of photographic materials, structure of photographic images, photometry, and reproduction. The book has real value for all photographers and special value to students of space photography. Moreover, it should be of interest to those in general astronomy, providing a good review of the subject along with photographic instruction.

MARJORIE B. SNYDER

Washington, D. C.

LETTERS

AUTHOR VS. CRITIC

I SHOULD like the opportunity to reply to the review of my book, *The Family Revolution in Modern China,* by F. L. K. Hsu (*Sci. Monthly,* **71,** 279 [1950]). I certainly do not view the volume concerned as definitive in any sense, but I also do not think that Professor Hsu's criticism gets at the heart of its inadequacies for the following reasons:

1. Professor Hsu has apparently overlooked the specific warnings in the volume as to the tentative nature of the material presented. He would have his readers believe that I have been far more dogmatic than is the case. He correctly notes that I consider the study as "a bare beginning" but he apparently fails to note that I have also stated:

> The results of this study do not masquerade as definitive, for it has not been possible either to see or to verify from facts gathered by others all the phenomena analyzed here. The data at present permit nothing in the nature of definitive statements on either the "traditional" or the "transitional" period in China because adequate statistical materials are not at hand and alternative materials on a large enough scale to replace statistics have not yet appeared. This study should be viewed as an attempt to set forth the best available set of hypotheses. I believe that this study does offer a systematic analysis which may be verified or disproved, in whole or in part, as material of a more definitive nature becomes available (p. xi).

At several other points the state of this work as a set of hypotheses is insisted upon (e.g., pp. xv, 54, 55, 64 [fn.], 70 [fn.], 257, 273, 306, etc.), and it might be added that so frequently was this point reiterated in the final draft of the manuscript that the publisher insisted on the elimination of many of the redundancies.

2. Professor Hsu states as an example of my failure to discriminate among materials, sources, etc., that ". . . in his discussion of incest Levy uncritically accepts the conclusions of R. Fortune and then contents himself with saying that he has also consulted other 'anthropologists' on this subject." If Professor Hsu will reread the passages on incest (pp. 18–21) and the article by Fortune referred to, he will find that my passage: (*a*) specifically points out what I consider, perhaps wrongly, to be certain inadequacies of Fortune's theory; (*b*) specifically attempts to state why they are inadequate; and (*c*) presents a theory quite different from that of Fortune. My attempt may be no better than Fortune's, but if it is not, Hsu does not tell why it is not, and it certainly cannot be described as "uncritical acceptance of the conclusions of Fortune."

3. Professor Hsu refers to my remarks on the remarriage of widows in "traditional" China. We are, it seems, in agreement that the widows of peasants remarried as a matter of course in "traditional" China. Professor Hsu is aggrieved that I did not point out that the remarriage of widows was "not considered bad by any level of Chinese society" prior to and during most of the Sung (A.D. 960–1279) period. In my book I used the term "traditional" China with some care. The passage criticized by Professor Hsu is on p. 46 (fn.). Only five pages before (p. 41) the use of the term "traditional" is specifically discussed. For reasons stated there I used the term to refer to China at the height of the Ch'ing Dynasty (A.D. 1644–1911). To call attention to my special referent for the term "traditional" and to avoid misleading the unwary in just these respects, the term appears throughout the volume in quotation marks. It appeared that way in the passage that caught Hsu's eye. I am not a scholar on the Sung Dynasty materials though, like Professor Hsu, I have been informed of the importance of this era as one of social change. My reason for not going into such questions was given along with the definition of "traditional" on page 41, and the importance of the Sung Dynasty was specifically mentioned in the discussion. How careful must one be to prevent misconceptions of this sort on the part of a reviewer?

4. Professor Hsu refers to some specific errors. For example, "Levy . . . fails to realize that his formalistic picture of the Chinese clan (pp. 48–51) has a very limited geographical application." On pages 49–50, citing and following the work of a Chinese anthropologist, I stated: "The center of the strongly developed *tsu* today is Central and Southern China—the Yangtze Valley in general and the provinces of Fukien and Kwantung." Does Professor Hsu care to limit it geographically still further, or has he failed to see the specific limitations cited? If the former, I should at least like to have his citation of authority for the contrary. If the latter, . . .

5. Professor Hsu hits the mark solidly when, citing another error, he says of the terms used by me to denote age period that the first halves of the terms were in common use, but the second halves were not. Those terms are terms like the following: infancy period, childhood period, adult period, old-age period, etc. The second half of the term in each case is the modern Chinese term for "period." Hsu is quite correct to note that in common parlance one did not speak of "old-age period" or "infancy period" but rather of "old age" or "old people" or of "infancy" or "infants." The term for "period" was, of course, added by persons in-

terested in analyzing such age distinctions. I must confess that my passage on these terms (p. 66) may be given the strict interpretation used by Hsu and is in error to this extent, and I must add weakly that it did not occur to me that my laxity in this respect would puzzle or mislead anyone.

6. Professor Hsu does not object in principle to my use of analysis to establish hypotheses about the facts and points out I am "not unaware of the dangers of this procedure." He then states that I claim to have eliminated these dangers by having subjected the passages concerned to "thorough outside criticism." This is a question of interpretation. After stating the dangers of this procedure (p. xiv) I added: "In support of this practice here it can only be said that both the 'facts' so derived and the theory so employed have been subjected to outside criticism." The use of the term *only* and the quotation marks around the term *facts* seem to me to speak eloquently for a more modest interpretation of the passages than that given it by Professor Hsu. Even as I reread it now I cannot see how he could have construed it to mean that I felt the dangers had been eliminated by the criticism. Mitigation of the dangers is the very most I meant to claim.

7. Finally, there is an issue of genuine importance between Professor Hsu and me. He agrees that the results of the methods I have used are not necessarily productive of false results. At no point in his review does he challenge specifically, or even mention, a single one of the main hypotheses advanced in the volume. He does not, for example, challenge specifically the material on sources of stress and strain as well as sources of strength in the "traditional" Chinese family system, the special structural problems posed for transition to industrialization, etc. He does point out, as I have done myself, that many (I would say virtually all) of the hypotheses I have presented are not proved and may turn out to be quite incorrect when we are in possession of more reliable evidence. I feel, however, that the fact that so many of the hypotheses starting from different points reinforce rather than contradict one another suggests, at least, though it does not rigorously prove, that there is some validity in these hypotheses or else a remarkable degree of coincidence and self-deception. Professor Hsu would go further than our mutual skepticism, however, and states: "There is no justification for Levy to mislead his readers with so much of the latter ("hypotheses about the facts" or "mere speculation"), especially since the *actual facts are accessible.*" (Parentheses and italics mine.) It is the italic passage that is of interest here. I challenge Professor Hsu to produce from this stock of *actual and accessible facts* anything like rigorous empirical demonstrations of the validity of his hypotheses insofar as they would disagree or agree with mine. One must not at the present stage of development of social science oversell its wares. If by actual and accessible facts on China one means rigorous empirical studies verifying specific states of affairs, I challenge their existence for any of the more general problems of Chinese social structure. I feel, perhaps wrongly, that at this stage the careful elaboration of hypotheses about these "facts" can be an important step in planning and directing the research that will be necessary to determine these "facts" rigorously. Without citation of any examples I do not find convincing Professor Hsu's statement that such materials are in existence.

MARION J. LEVY, JR.
Department of Economics and Social Institutions
Princeton University

I PRESENT a brief reply to Dr. Levy. The numbers used refer to sections of his letter.

1. Dr. Levy argues that he did not intend to say that his volume was a definitive one. But in his introductory comments on other writers on the subject he said that most of the writtings, "insofar as they are scientific analyses, lack definitive character" (p. xi).

2. In his treatment of incest Levy merely referred to the obsolete work of R. Fortune (1932) but failed to note not only the works I specified in my review but also a whole series of works of Meyer Fortes (1936), Brenda Seligman (1935), and Leslie White (1948). (There were some publications on this subject in 1949, but these might have appeared after Dr. Levy completed his book.) Had Dr. Levy taken notice of these relevant materials, he would have realized his linkage between incest taboo and maintenance of family solidarity is untenable.

3. Dr. Levy did not restrict his use of the term "traditional China" to A.D. 1644–1911. On the very page where Dr. Levy defined it, he said: "The term 'traditional' applies to those institutionalized patterns which for the most part trace their pedigree with remarkably slight change well back into Chinese history, sometimes going as far back as the Han emperors (206 B.C.–A.D. 220)." Furthermore, Levy made many more references to older periods of Chinese history in discussing various topics (pp. 39, 46, 48, 55, 59, 176, etc.).

4. The question here is, again, not that Levy did not enter a note of limitation, but the correctness of his statement of limitation. Does Levy realize that the work of the Chinese anthropologist on whom he relied in no way gives any basis for the alleged strength of Chinese clans in "Central and Southern China, etc"? If he had exercised his critical powers he would at least have looked for some source of confirmation or refutation of his assertion. For example, he could have looked into Vol. VII. Nos. 1–2, of the *Quarterly Bulletin of Bibliography* (in Chinese, 1946), published by the National Peiping Library; he might have found some useful information on genealogical books that would throw a different light on his statement concerning the strength of Chinese clans.

5. Here Dr. Levy agreed with my criticism 100 per cent.

6 and 7. I never doubted that Dr. Levy had sub-

jected his deductions to "thorough" criticism, but I did, and still do, wonder about the results of his deductions even after they had been subjected to such "thorough" criticism. Here my criticism has caused Dr. Levy to take refuge behind the plea that one must not, "at the present stage of development of social science, oversell its wares." What I emphasized was, however, not the need for overselling our wares but exactly the reverse. I asked Levy to look at some "actual and accessible facts" before pushing ahead with his theories. This Dr. Levy had failed to do and it is not difficult to show how. For example, in his analysis of the economic situation of Chinese peasants, he quoted Professor Chen Han-Seng's *Study of Kwangtung Province* alone but completely ignored the works of J. L. Buck (some of which he merely listed in his bibliography and vaguely praised on p. 273). What is Dr. Levy's basis for citing Professor Chen's tenancy figures limited to one province and omitting Professor Buck's much more extensive results? And if he wished to restrict himself to intensive local studies, why did he not compare the Kwangtung figures with those from Yunnan Province by H. T. Fei and T. Y. Chang (whose work Dr. Levy again merely listed in the bibliography)? Did Dr. Levy not know that the Yunnan tenancy figures are again very different from those of Kwangtung and would vitiate his subsequent arguments?

Another example of omission of "actual and accessible facts" concerned Dr. Levy's uncritical acceptance of a statement that juvenile delinquency had increased in China "because it is a familiar story in the West." My position is that we have not only no basis for accepting this conclusion, but that available figures show modern China and the U. S. to be very different in this respect. This Dr. Levy could have found out by a comparison of specific crime figures from the United States including *Statistics on Crime and Criminals*. Walter A. Lunden. Philadelphia: University of Pennsylvania Press, [1942]) and from China (including a volume in Chinese: *Yearbook of the Ministry of Interior*. Shanghai: Commercial Press. Pp. 1393, 1403, 1438, 1477 [1936], available in Harvard, Columbia, and Chicago University Libraries). Had Dr. Levy looked into these "actual and accessible facts" he would even have found other significant differences between China and the U. S., all of which, incidentally, would have drastically affected Dr. Levy's conclusions on *The Family Revolution in Modern China*.

In reading Dr. Levy's book I merely followed two basic principles: (1) I did not take any of Dr. Levy's statements in isolation but considered all of them in the context of his other statements in the same book. (2) I judged Dr. Levy's pronouncements not only by facts which he presented but also by "accessible facts" which he omitted. I wonder if, in spite of his reply, Dr. Levy considers these two principles to be unsound.

FRANCIS L. K. HSU

Department of Anthropology
Northwestern University

LINGUISTICS

ABOUT three months prior to the appearance in THE SCIENTIFIC MONTHLY of an article pointing out the practically insuperable difficulties besetting the creation and efficient use of an artificial international language (Charles E. Whitmore. The Problem of a Universal Language. **72,** 337 [1950], there occurred in Paris (August 5–12, 1950) the thirty-fifth annual international congress of Esperantists, with a registered membership of more than 2,500 persons from 34 different countries and with an actual attendance of more than 2,000 persons. At the opening session (held in the Sorbonne) addresses of welcome were made by representatives of the French Ministries of Education, Commerce and Industry, Postal, Telegraph and Telephone Services, and also by the Assistant Director of UNESCO. Not only was the business of the congress transacted entirely in Esperanto, but even those addresses of welcome from outside the organization were couched in this international language—except that the UNESCO official spoke in French. Official representatives from seven countries (Austria, Belgium, Brazil, The Netherlands, Norway, Sweden, Uruguay) also presented the greetings of their respective countries to the opening meeting.

Although this congress was the thirty-fifth of such annual international congresses, held in various cities, mostly on the continent of Europe, the first one was held forty-five years ago, war conditions having prevented their occurrence during the years 1914–19 and 1940–46; that first congress, in Boulogne-sur-mer, gave to the world the first public incontestable proof that intercommunication among persons of differing native tongues via a properly constructed artificial language is completely easy and satisfactory—in other words, that Esperanto works. It has worked ever since, for all who care to use it. Their number is still probably small, estimated as perhaps only a few well-scattered millions.

Whitmore's article reviewing the reasons why an artificial international language is deemed impractical and unlikely, none of which reasons are new,* makes some statements and asks some questions that it seems fair to answer for the audience that has heard them:

Dr. Whitmore says "the variety of solutions already proposed [for a "world" language] has produced a conflict of opinions that has not so far helped to put the problem in a clearer light. It is worth while to consider some of the fundamental aspects of that prob-

* It was in 1887 that Esperanto was first promulgated in Europe, and it was only shortly thereafter that it was brought to the attention of the United States through efforts of the American Philosophical Society (in a translation which Henry Holt & Co., of New York, published). In the years intervening since that time, all the conceivable arguments against its feasibility and desirability have undoubtedly already been put forward. A short summary of the history of the international language idea is given in *The Story of Language*, by Mario Pei, from which Dr. Whitmore evidently drew both inspiration and data.

lem before any choice among proposed solutions can profitably be made." The main inaccuracy here is that there is at hand *no* "variety of solutions" from which Whitmore or anyone else can make a choice. In actual fact, there is now before the world just one solution for the international language problem. That one is Esperanto. It had precursors, it had competitors, it had enemies who wore the sheep's clothing of would-be improvers; but they have all disappeared. Basic English, which may perhaps be still as much alive as it ever was, is not a competitor of Esperanto, being fundamentally just a scheme to make the teaching of English to foreigners a little easier. The idea is said to have encouraged the proffer of Basic Spanish, Basic Russian, and Basic Chinese, which is rather amusing. As a lever to help put English into the position of an acceptable international language (which of course is the desire of all nations whose languages any outsiders consent—or are forced—to learn), it might as well go down the drain with the rest of the schemes that are now "relegated to the archives."

Whitmore remarks, "Some enthusiasts maintain that we can grow to love the intrinsic beauty of an artificial language; but the fact will require a long time to demonstrate, and a still longer one for the love to develop on any large scale. The added language, whatever its nature, would have to be supported by a durable and uniform enthusiasm. How many such can history show?" Aside from the fact that history does show one—Esperanto—which presents some such demonstration by its half century of fairly durable and uniform enthusiasm for what early Esperantists used to call *la kara lingvo*—who could "love" Basic English? Again, why bother about loving the language? Do we have to love asphalt highways or electric trains or automobiles because these artificial creations are more useful to most of us than dirt roads and horses?

In his last paragraph Whitmore says that "Every living language is supported by a body of users whose native tongue it is and who stand behind its applications and extensions. Where is this support to be found for an artificial language?" Apparently remembering that Esperanto is so supported (even more firmly in view of the fact that it is *not* the native tongue of any of the supporters), he hastens on to declare, "A scattered body of adherents in many lands, whose enthusiasm may wane and whose descendants may not share it, is not enough." Why not? What could be more ideal than a scattered body of adherents in many lands? Even the enthusiasm of many of the early Christians waned now and then, especially under persecution; and they died, generation after generation, like any other people; and not all their descendants may have remained Christian! In the face of such a pessimistic argument we may be permitted to assure Whitmore that enthusiasm seems to have grown instead of having waned ever since Esperanto was given to the world; many Esperantists have died of old age or of casualties in the two world wars, but evidently others have carried on the torch.

Dr. Whitmore suggests that "the chances of finding, at any given spot, a person who uses one of the artificial languages . . . must be . . . small." For any international language scheme except Esperanto, such chances are of course nil. In the case of Esperanto the situation is a little better. In many cities and towns, even villages, there is an Esperanto "consul," whose duty it is to respond to calls and inquiries from visiting Esperantists, help them make contact with wanted persons or firms, show them such courtesies as he can. There are not yet nearly enough consuls; but that there are enough to be listed in a modest directory is certainly a move in the right direction. Furthermore, in many cities one may look in the telephone directory under Esperanto, and at the indicated number someone will give him addresses, any information possible, perhaps an invitation to attend the next meeting of the local Esperantist club.

Finally, Dr. Whitmore adds that the chances are still smaller of finding that a needed book or article has been translated into an artificial international language; may we change this to THE international language, so that it can be answered? It is true that Esperanto does not yet offer a complete body of translations of all technical works issued in all countries of the world! The number of scientific publications of both private individuals and of a few governmental bodies in Esperanto is still pitifully small. There is not even in existence any series of abstracts, although obviously this would save much time and money for would-be users. There should, of course, be a bureau somewhere (doubtless Washington) to receive, classify, index, and publish such a series of scientific abstracts in Esperanto. Perhaps readers of THE SCIENTIFIC MONTHLY know an intelligent multimillionaire who will establish a foundation for this purpose.

IVY KELLERMAN REED

238 Griffin Street
Santa Fe, New Mexico

FULLER'S FOLLY?

PROFESSIONAL educators should be very grateful for "The Emperor's New Clothes," by Professor Fuller, in THE SCIENTIFIC MONTHLY for January 1951. The earnest worker in any field appreciates kindly, constructive criticism.

But this paper has an even greater value. It was presented originally as the address of a chapter president of Phi Beta Kappa. It was given again at a meeting of the AAAS and then was published in THE SCIENTIFIC MONTHLY. The educator, then, so it would seem, can give this to his students as representative of the very highest scholarship and as typical of the best in research. Professor Fuller bases his conclusions upon research. He says (p. 35), "During the past ten years I have pursued, on trains, and in planes, hotel lobbies, barbershops, and soda fountains, a private research project among businessmen and practitioners of the law, medicine, and other professions." On the next page he displays his

statistical analysis of results of 106 interviews, including three in the professions (this shows one in each of three professions over a period of ten years). This is a research worthy of Phi Beta Kappa and THE SCIENTIFIC MONTHLY, pursued by an eminent scholar and scientist! How much simpler this is than what college of education students have been led to believe! To obtain such evidence, they have been told, there must be a carefully designed experiment involving adequate sampling, well-chosen tests, rigid statistical analysis, and the like. Now they know that 106 interviews in trains, barbershops, and the like, scattered over ten years are sufficient. They may assume, too, we would judge, that in the same way that we can weigh the success of various educational procedures one man can discover the effects of radiation on plants.

The educator notes from our example of scholarship that a few quotations from unnamed sources are approved in the best circles. He may address the honorary society in education on the topic of genetics and quote, without naming him, Lysenko as an authority, safe in the assurance that this is what scientists do. And to get a true picture of the characteristics of a group it is not necessary to sample the entire population. Quote a few instances, all from one extreme, and assert the typicalness. (See Fuller's proof of the poor English composition of college students.) When we consider not only the scientific method as exemplified in this research, but, also, the open-minded attitude, the temperate language, and the eagerness to work together for the common good with which the research report is written, surely we will wish to recommend that each student of education be given a copy to keep constantly before him.

The above is written as an educator *might* view the paper by Professor Fuller. The present writer, however, who, as it happens is privileged to wear both the Phi Beta Kappa and Sigma Xi keys—tarnished as they are by contact with professional education—believes that the article has one, and one only, value for education. It should be in the hands of every student of education marked as Exhibit A on an oft-disputed question. It shows clearly that one may have erudition without scholarship and that one may attain high competence in the techniques of science without coming into possession of the attitude of a scientist.

D. A. WORCESTER
(*Secretary, Section Q*)

Teachers College
University of Nebraska

THE article of Professor Fuller in the last SCIENTIFIC MONTHLY expresses so well my opinion and that of many of my colleagues that I would like to have a number of copies available for use in our university. . . .

FRED R. CAGLE

Department of Zoology
Tulane University

WOULD it be possible to obtain about ten copies of Professor Harry Fuller's article "The Emperor's New Clothes"? This is certainly an excellent piece of work and deserves to be set before college administrative officers throughout the country.

WILLIAM G. CRANE

Department of English
The College of the City of New York

. . . I SHOULD like very much to have twenty-five reprints of Dr. Fuller's article. It is an excellent and timely discussion of a very serious situation. . . .

J. O. EIDSON

Spartanburg, South Carolina

I AM very much interested to know if you have reprints available of Dr. Fuller's article. Very soon the entire state of New York is to change over to this new life adjustment curriculum as worked out by the education department in Washington. As of this year they are dropping regents' examinations, except as they will be given and kept on file in the local school—as a first step toward eliminating this type of scholastic achievement.

ELMER A. FINCH

Amityville High School
Amityville, New York

I READ with great interest the article by Professor Fuller in the January issue of THE SCIENTIFIC MONTHLY. I wonder if it would be possible to obtain a dozen reprints of that article.

FREDERIC A. GIERE

Department of Zoology
Syracuse University

IN THE January 1951 issue there is an article by Harry J. Fuller. If at all possible, I should like to order one hundred copies of this article.

JOHN H. HOLLOMON

Research Laboratory
General Electric Company
Schenectady, New York

IS IT possible to obtain reprints of the excellent article by Dr. Fuller, . . . and could any part of it be used in a newspaper. Could it be used in its entirety? I am especially anxious to have it presented to the citizens of my community.

NORMA LEVEQUE

Boulder, Colorado

DEAR PROFESSOR FULLER:

THE *New Outlook* magazine is very much interested in reprinting your article. . . . We are very anxious to expose the lay public to your views and we would be extremely grateful for your permission to reprint this material.

HYMAN LISCHNER, M.D.

Los Angeles, California

ENCLOSED is our purchase order for reprints of the article by Dr. Fuller.

CARROLL O'SULLIVAN, S. J.

Office of the Rector
University of San Francisco

WILL you be kind enough to let me know the cost of 100, of 200, and of 500 reprints of the article by Dr. Fuller?

SYDNEY STEELE

Wilmington, Delaware

IF YOU desire a scientific consideration of Dr. Fuller's recent ex parte fulminations, if you wish the weight of such carefully controlled work as the "thirty schools experiment" that extended through eight years thrown into the balance against his off-the-cuff jottings, no doubt you know many men and women well qualified to undertake the task.

Since Dr. Fuller has chosen, however, to appeal to naïve, "common-sense" perception and to stir up polemical, uncritical emotions, perhaps a layman's satire will be the most appropriate response.

Ergo, I offer you:

Clothes Make the Man; or, *The Naked Truth*

Oh, Fuller was a doughty wight,
Who laid the schoolmarms low;
And questions as to what was right
He settled with a blow.

With such a sound latinity
His titles did resound
That some may be too awed to see
Much else he said was sound.

Between his scorching lines we trace
The picture of the happy day
When schools would take the bright
with grace
And turn the dumb away.

And who would question that the fools
Should not be taught at all
If doing so must change the schools
To stir up Fuller's gall?

So let us swell subversive cells
Within the P.T.A.
To put the skids 'neath stupid kids
Throughout the U.S.A.

When Fuller's finished his campaign,
How happy we shall be!
And when he sallies forth again,
May I be there to see.

WILLIAM H. NEWBERRY

Alton, Illinois

DECRY LACK OF GRAMMAR

Dartmouth Teachers Report Many College Men Faulty in English

Special to THE NEW YORK TIMES

HANOVER, N. H., Jan. 14—Two Dartmouth College instructors who are in charge of the college's remedial writing clinic issued an appeal to the nation's secondary schools to return to training their students in the fundamentals of good English.

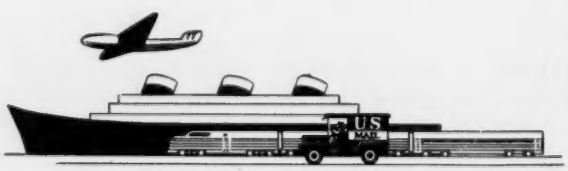
Donald L. Cross and Harold G. Ridlon, Jr., criticizing the so-called "progressive type" of education, said that many students entering the clinic here for assistance were graduates of such institutions. . . .

"Many of them," Mr. Cross said, "have little idea of correct spelling, punctuation and grammar."

A recent report by the college's committee on student English headed by Professor Frank G. Ryder, said that an increasing number of men in business and industry decried the inability of many college graduates to write even simple and correct business letters and reports.

HELP! I am being swamped by requests for reprints. You might be interested to know that the requests for reprints in quantity exceed the number of requests for single reprints. If it is possible, I should like to double my order.

HARRY J. FULLER

Department of Botany
University of Illinois, Urbana

THE excerpts above represent only a small fraction of the letters received from parents, educators, employers, and others who deal with the end product of the schools of education. A full-length reply to Dr. Fuller will appear in an early issue.—Editors.